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Photo of Trans-atlantic phone call with Brighton, England (see page 541).

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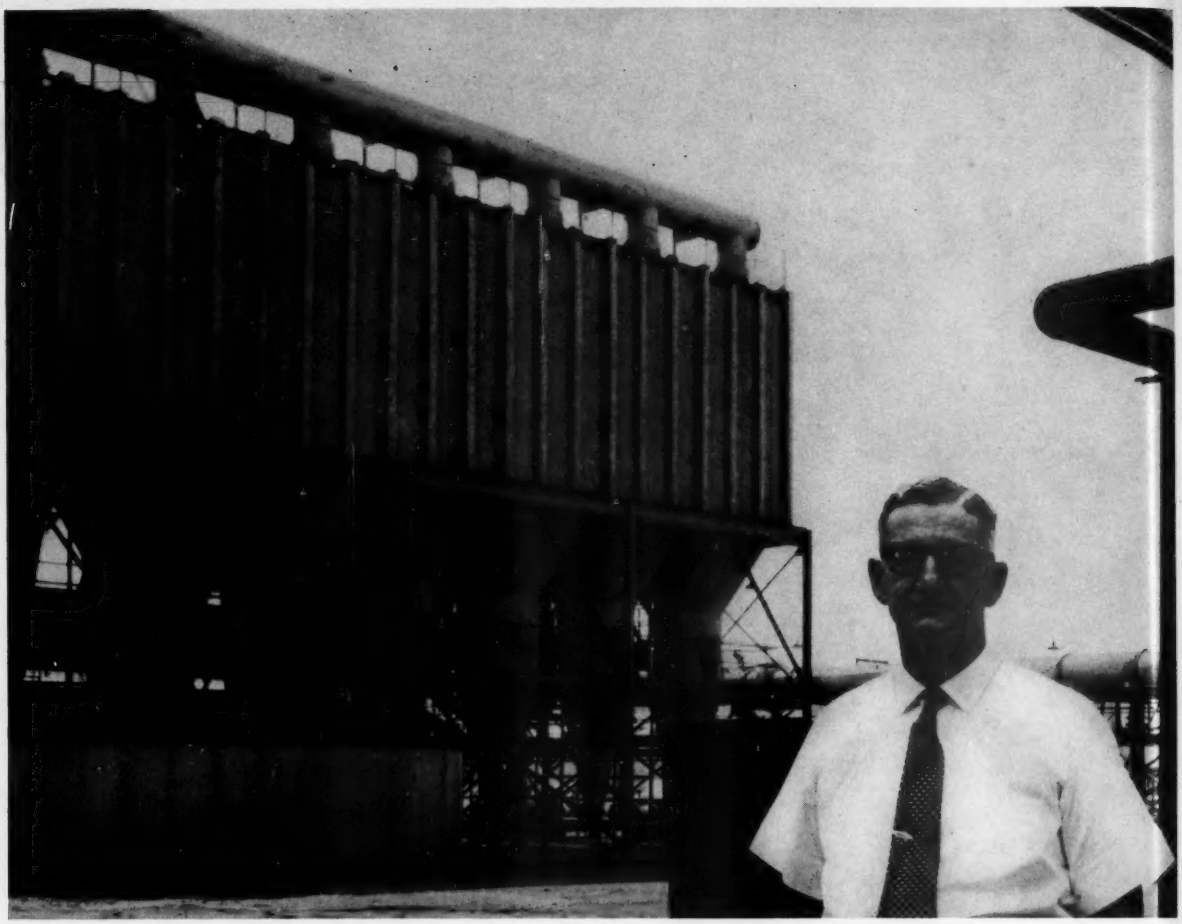

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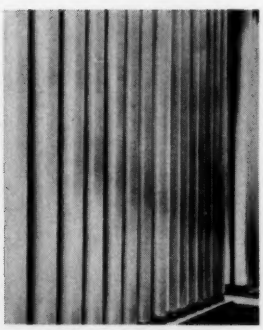
CABOT CORPORATION, FRANKLIN, LA.



A typical installation of Fiberglas filter bags. Their high temperature range often makes costly cooling towers unnecessary.

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APCA ABSTRACTS

Vol. VII, No. 6 November 1961

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GENERAL ASPECTS OF AIR POLLUTION

3952. The Clean Air Act, 1956—Its Implementation and Application to Vessels. T. L. MACKIE. *J. Roy. Inst. Public Health and Hyg.* (London) **22,** 256–65 (1959).

The port health authorities have been assigned powers to exercise legislation over, with provisions to control excessive emissions of, dark smoke from vessels within their districts. It is hoped that the removal of the obligation of proving a nuisance and the simplification of other unwieldy legal procedures, will stimulate efforts for direct action against offenders. At the port of London for one year, the foreign-going arrivals numbered 6000 under the British flag and 9000 under other flags, together with 12,000 coastwise arrivals which were predominantly under the British flag and about 500 harbor craft of various types. By far the greater number of the coastwise ships had hand-fired coal burners and their behavior constituted the heaviest task for port health authorities since they could also operate in so many ports in such a relatively short space of time. The regulations are cited as the Dark Smoke (Permitted Periods) (Vessels) Regulations, 1958, and came into operation on June 1, 1958. The schedule, outlined as to class of case and permitted period for emission of dark smoke, is given and discussed in the text. It is felt that the beneficial effects of an effective and persistent enforcement of the law at one port will eventually become manifest in all ports and the nation will reap the benefit of the aggregate port health effort thus reconciling any disparities in available numbers and competence of local inspectors. The pattern of policy, preparation, and application is proving well founded and favorable in the Port of London and satisfactory success is being achieved. (LC)

3953. Air Pollution Control and the Gas Industry. M. STERLING. *J. Air Poll. Control Assoc.* **11,** 354–61 (Aug. 1961).

Gas is used in many applications where severe local, or area-wide air pollution problems could result; such as in heating of varnish kettles, heat treating or annealing of metals, secondary smelting of nonferrous metals, kiln drying operations, and the incineration of waste materials. The main subject of this article is the latter application. Since the inception of the test program 35 different model incinerators were tested, 23 of these were submitted for evaluation, and 10 fully passed the requirements. The 3 rejected by the test procedures have passed present AGA test requirements. The performance characteristics of the new incinerators are significantly better than the dehydrating (low input) or older high input incinerators from a smoke, odor, and flyash emission standpoint. Additional developmental effort will be necessary to permit reduction in the relatively high percentage of CO emissions from the new incinerators. No data were obtained on the extent of emissions, such as aldehydes, unburned hydrocarbons, oxides of nitrogen, sulfur dioxides, etc., from the new domestic incinerators. A preliminary evaluation of 1 electrically-fired incinerator indicated a general performance about on par with the low input units.

SOURCE, POLLUTANTS, CONTROL OF AIR POLLUTION

3954. Catalytic Treatment of Nitric Acid Plant Tail Gas. H. C. ANDERSEN, W. J. GREEN, and D. R. STEELE. *Ind. Eng. Chem.* **53,** 199–204 (Mar. 1961).

Catalytic treatment of nitric acid plant tail gases containing O_2, NO, NO_2, and H_2O in N_2 was investigated to control an air pollution problem. With platinum or palladium as catalysts, the oxides of nitrogen and oxygen are reduced to a few ppm. at space velocities of 60,000 standard $ft.^3/hr./ft.^3$ catalyst and higher, using any reducing gas in slight excess over the total oxygen. When O_2 in the tail gas is greater than 2.8 to 4.2%, 2 catalytic stages with intercooling are used to obviate excessive temperatures on the catalyst and vessel. Where air pollution abatement is not required, catalytic treatment of the tail gas is interesting to produce additional heat for power recovery. A selective catalytic process for nitrogen oxides removal is described. NO and NO_2 are reduced by ammonia in slight stoichiometric excess over these oxides but below the total oxygen equivalence.

3955. Problems of Corrosion, Blockage, and Smut Emission from Combustion Processes. R. ASHMAN. *Steam Engr.* (London) **30,** 255–9 (May 1961).

A report is given of investigations into the above problems and the introduction of a system to overcome these difficulties. This system, which is particularly applicable to oil-fired boilers, is claimed to be inexpensive to install, simple to operate and in most cases the operating costs have been more than offset by the saving in fuel and maintenance costs. Known as the DCP system, its main feature is the reduction of sulfur trioxide to sulfur dioxide by the injection of a chemical comprising mainly precipitated carbonates of magnesium and calcium into the flue gases. (Fuel abstr.)

3956. The Behavior of Dense Stack Gases. F. T. BODURTHA, JR. *J. Air Poll. Control Assoc.* **11,** 431–6 (Sept. 1961).

Model tests on the behavior of dense stack gases were performed. The model tests were representative of a neutral (adiabatic) temperature gradient in a full scale atmosphere, since no thermal modification of the wind tunnel air stream was employed. This study demonstrated that dense stack gases descend rapidly to the ground, and the results indicated that dense stack gases should be discharged vertically upward from a stack with the min. practicable diam. This min. diam. results in the max. stack gas velocity for a given flow-rate. Collection equipment may be necessary in some cases to prevent pollution or a potential safety hazard. These tests also emphasize that previously existing atmospheric dispersion equations cannot be used with reliability to estimate the concentration of dense stack gases at the ground.

3957. The Efficiency of Small Gas Absorbers. S. CALVERT and W. WORKMAN. *Amer. Ind. Hyg. Assoc. J.* **22,** 318–24 (Aug. 1961).

The factors affecting the efficiency of sampling for vapors by means of bubblers and absorbing solutions are discussed. A mathematical presentation of the theoretical calculations of efficiency, and formulas for practical application of calculations of efficiency are given. The methods presented are sufficient for estimating collection efficiencies for most practical purposes. Results of essentially the same methods for treating physical absorption and absorption with chemical reaction have been compared with experimental data in a previous paper by the authors.

3958. [Fighting the Toxic Gases of the Atmosphere.] Guerre aux gas toxiques de l'atmosphere. L. FASSINA. *Chim. et Ind.* (Paris) **84,** 529–31 (Oct. 1960).

An attempt was made to perfect a chemical catalytic system for the oxidation of toxic carbon monoxide with the resulting formation of the more-or-less harmless compound, carbon dioxide. This was done during the combustion of petrol or gas-oil and air vapors in the cylinders of the engines of operating vehicles. The device employed the use of MnO_2, to form, in the presence of moisture, the compound $Mn(OH)_2O$. This latter form combines with the CO to produce CO_2 and the unstable compound $Mn(OH)_2$, which spontaneously absorbs oxygen from the air and again forms $Mn(OH)_2O$. (LC)

3959. Studies on the Analysis of Hydrocarbons from Incinerator Effluents with a Combustible Gas Indicator. M. FELDSTEIN. *Amer. Ind. Hyg. Assoc. J.* **22,** 286–91 (Aug. 1961).

A combustible gas indicator with a 10 to 1 sensitivity scale has been studied in relation to the measurement of C_2 and higher hydrocarbons from incinerator effluents. Incinerator effluent samples are collected in evacuated stainless steel 34 l. tanks, and the integrated samples analyzed with the combustible gas indicator. The instrument was modified in that the drying agent was replaced with ascarite, and a small diaphragm pump was substituted for the rubber aspirator bulb. Response to carbon monoxide and hydrocarbons was differentiated by

* Shows new journals added in this issue. See list at end showing addresses.

APCA ABSTRACTS

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means of a tube of activated carbon which adsorbed hydrocarbons, but did not adsorb carbon monoxide or methane. The instrument can be used to differentiate between incinerators emitting less than 50 ppm. total hydrocarbons, and those emitting higher concentrations of hydrocarbons. Precautions to be observed in the use of the instrument for the measurement of C_2 and higher hydrocarbons are discussed. (Author's summary)

3960. An Evaluation of the Aerometric Probe. P. A. HUMPHREY. *J. Air. Poll. Control Assoc.* **11,** 362–3, 383 (Aug. 1961).

Disadvantages and limitations of conventional methods to probe the 1st few thousand ft. of the atmosphere and the recent availability of a variety of inexpensive radio control devices have brought about the development of a radio controlled drone for meteorological and air quality observations. The drone, with a 10-ft. wing span, is launched from an 8-ft. single rail catapult. The flying speed of the drone is 20–25 mph. Because of its small size, it creates less disturbance of the atmospheric conditions being observed than a full sized aircraft. With the model airplane radio control transmitter it may be operated within a range of $^1/_2$ mile. Although the prototype drone has been flown more than 40 times, a sufficient number of consecutive safe flights are needed to give assurance to regulatory agencies that operations can be safety conducted near or within cities. It is hoped that the aerometric drone will have its instruments and sampling devices calibrated possibly in a wind tunnel. Then when it is vectored through a plume of air pollution, it will be able to obtain meteorological measurements, particulate or gas samples and an air quality concentration profile.

3961. Probe for Studying the Deposition of Solid Material from Flue Gas at High Temperatures. P. J. JACKSON and E. RAASK. *J. Inst. Fuel* (London) **34,** 275–80 (July 1961).

A simple and robust air cooled probe providing a reproducible and easily manipulated target of known variable temperature has been used to study the deposition of fuel ash constituents from flue gas in boilers. A reliable auto controller is available for long exposures and the temperature recorder is a standard range instrument. The rapid methods of chemical analysis developed for use in this work require no special or expensive apparatus. The use of the probe establishes a valuable link with research in the laboratory. In application to problems of boiler fouling and corrosion it is versatile, and is suitable for collecting fused slag formed from a flame and for assessing precisely the deposition of sodium from flue gas in an oil-fired boiler, containing about 2 $\mu g.m.^{-3}$ of sodium. Simultaneous measurements can be made at a wide range of temperatures.

3962. [Removal and Deodorizing of Gaseous Emissions from Fish Meal and Other Factories.] Die Beseitigung und Desodorierung gasförmiger Emissionen von Fischmehlfabriken und anderen Betrieben. H. H. KURMEIER. *Wasser Luft u. Betrieb.* (Wiesbaden) **5,** 7–10 (Jan. 1961).

Effective procedures, which are not too expensive for such an unproductive operation, need to be developed for the removal of the gaseous emissions from those factories processing fish meal and similar products. The emissions are very obnoxious as to odor and may be harmful. The primary problem is the removal of SO_2 from the gases from boiler firing. Theoretically removal of this emission is possible but so far it has been very costly. This report discusses a procedure which is not only applicable in the large international field of the fish meal industry but which, perhaps, may also contribute a solution to the problem of the removal of the SO_2 from boiler gases. A schematic sketch of a pilot plant for the removal of such emissions, based on the use of a hydro-extractor and incorporating a natural limestone filter column, is shown in figure 1. (LC)

3963. [Investigation on the Influence of Cement Kiln Dust on Soil and Plants.] Untersuchungen über den Einfluss von Zementofen Flugstaub auf Boden und Pflanze. F. SCHEFFER, E. PRZEMECK, and W. WILMS. *Staub* (Düsseldorf) **21,** 251–4 (June 1961).

Investigations in a 2-yr. field experiment on the influence of cement kiln dust on soil and plants have shown no damage to the plants by sedimentation of cement kiln dust in the case of 4 agricultural crops. However, the possibility of an indirect influence of the plant yield exists and the substances contained in the plants by the soil, changes in the soil reaction, and nutrient. Under certain circumstances this may lead to impairment of plant production. This can be counteracted by agricultural counter measures such as constant supervision of the soil properties and soil examination. (English summary cond.)

3964. Sample Collection Techniques for Combustion Sources. Benzopyrene Determination. R. L. STENBURG, D. J. VON LEHMDEN, and R. P. HANGEBRAUCK. *Amer. Ind. Hyg. Assoc. J.* **22,** 271–5 (Aug. 1961).

In evaluating combustion processes for their contribution of benzo(a)pyrene and other potential carcinogens to the atmosphere, the materials of interest may be lost during sampling unless the collection temperature is controlled. Cooling of the gases under both wet and dry conditions has been tried. This study demonstrates that collection of benzo(a)pyrene from high temperature gas streams can be effectively accomplished by filtration after cooling the gas stream to or near ambient temperatures. A series of water bubblers and condensate traps immersed in an ice water bath, followed by a high efficiency filter proved to be a satisfactory technique. (Authors' abstr.)

3965. Selection of Air Pollution Control Equipment. A. J. TELLER. *Ind. Water & Wastes* **6,** 21–6 (Jan.-Feb. 1961).

A major aspect of air pollution control practice is the economic removal or recovery of noxious or toxic gases from waste streams before venting. The selection and design of equipment for efficient removal of the gaseous components can be obtained, as with other types of process equipment, by application of basic chemical engineering principles. A significant factor in the choice of air pollution equipment is the controlling phase in the absorption process. In general the solvent is chosen on the basis of cost, selectivity, and high degree of solubility for the solute gas. The equipment types considered were: packed tower, tray tower, and venturi cyclone separator. Based on efficiency calculation the requirements were established as shown in table 8. On the basis of the characteristics of the equipment obtained, and the restrictions placed on the operating unit, the packed tower was chosen for the specific application. With slight changes in requirements for air pollution control systems, the equipment to be utilized can vary significantly. The application of fundamental engineering analysis is necessary for making an effective choice.

ATMOSPHERIC PHENOMENA, DISPERSION, EMISSION

3966. Some Observations on Smoke Plumes. G. T. CSANADY. *Intern. J. Air and Water Poll.* (London) **4,** 47–51 (June 1961).

The plume at Tallawarra power station was photographed many times to obtain the mean position. The observations were plotted in terms of appropriate nondimensional variables and compared with the observations of Bosanquet *et al.*, as well as the theoretical results of Priestley and Sutton. Within approx. 1500 ft. from the source good agreement with theory was found. Wind velocities were measured by noting the time taken by a given configuration in the plume to travel a known distance. Other atmospheric variables were not measured, but all observations were carried out on clear spring days in moderately strong wind.

3967. Valley Wind Phenomena and Air Pollution Problems. B. DAVIDSON. *J. Air Poll. Control Assoc.* **11,** 364–8, 383 (Aug. 1961).

This paper summarizes the aspects of valley wind phenomena which are particularly relevant to air pollution problems. The method of approach is, 1st to discuss specific examples of isolated aspects of a valley wind and then to indicate how the individual aspect may enter into the over-all pollution of a community. The data discussed were obtained from a fully instrumented micrometeorological tower at a site near Peekskill in the Hudson River Valley 1955–57, and in a group of valleys in southern Vermont during the summers of 1957 and 1959. The range of prevailing wind speed for the atmospheric

observations was 15 to 30 mph. This type of eddy wind system is highly intermittent and depends on the strength of the prevailing wind, the thermal stability of the air, and the angle of the wind direction with respect to the ridge line. The diffusion coefficient is sensitive to the relative position of the source with respect to the ridge line and to the direction of the prevailing flow. It is certain that under unstable conditions with winds normal to the ridge line, the lateral diffusion coefficients are much larger than they would be under flat terrain conditions.

3968. Meteorological Factors Affecting Particulate Air Pollution of a City. R. R. DICKSON. *Bull. Amer. Meteorol. Soc.* **42,** 556–60 (Aug. 1961).

Due to its utility in handling joint functions, the method of coaxial graphical correlation is used to relate particulate air pollution at Nashville, Tenn., to various meteorological factors. The derived relationship applied to test data yielded an average absolute error of 38.3 $\mu g./m.^3$ and root-mean-square error of 59.3; these results are clearly superior to a climatological control forecast using seasonal average concentrations. Graphical analysis and supporting correlation ratio computations suggest that small amounts of precipitation may be very effective in cleansing particulate matter from the atmosphere, rendering further precipitation of little consequence. The analysis emphasizes the importance of wind direction in governing air pollution concentrations at a point, suggesting that point measurement of particulate concentrations may have little representativeness when applied to an area the size of a city. Particulate matter concentration is found significantly correlated with day of the week (weekday-weekend groupings), offering an avenue for improvement of results. (Author's abstr.)

3969. On the Dispersion of Large Particles from a 15-M Source in the Atmosphere. K. D. HAGE. *J. Meteorol.* **18,** 534–9 (Aug. 1961).

In a series of 9 experiments embracing a range of wind speeds and stability conditions, fluorescent-dyed glass microspheres of nominal diam. 100 μ were emitted continuously from a point source of 15 m. over gently rolling prairie. The particles were collected on flat plate adhesive sampling surfaces at ground level along arcs between the source and a distance of 800 m. The observed cross-wind integrated deposits are compared with the predictions of Rounds' solution to the K theory of eddy diffusion and with Godson's modification of Rounds' solution. Some evidence is provided to suggest that, in certain cases, measurements of vertical temperature gradient and wind speed profiles between ground level and emission height are not sufficient to provide unique or reliable indicators of the intensity of vertical turbulence for the purpose of predicting the dispersion of particles. (Author's abstr. cond.)

3970. Smoke Observations on a 10-cm. Radar. H. W. HISER. *Bull. Amer. Meteorol. Soc.* **42,** 621–5 (Sept. 1961).

Smoke can be readily observed on radars at nominal ranges and may be reported as a precipitation echo by the uninitiated observer. An experienced observer can usually discern the difference between smoke and precipitation echoes by use of an R scope. In these examples, it is believed that the radar was detecting the large charred carbon particles in the smoke plumes. Smoke observations by powerful radars with highly sensitive receivers might prove useful in forest fire location and in studying atmospheric motions such as thermals. (Author's summary).

3971. Short Range Atmospheric Dispersion Measurements from an Elevated Source. N. F. ISLITZER. *J. Meteorol.* **18,** 443–50 (Aug. 1961).

Dispersion measurements of a tracer, uranine dye in solution, were made out to 2 miles from the release point in unstable atmospheres. The tracer was released from the top of a 150-ft. tower and sampled at ground level by 100 high vol. air samplers. Some 16 releases for 30-min. periods were analyzed. Techniques of dispersal collection and analysis of the tracer are included. Meteorological measurements during the tests included vertical and horizontal wind direction fluctuations at several levels on the 150-ft. tower and vertical temperature difference. Measured air concentrations agree with those predicted from a meteorological model using wind direction variances as dispersion parameters. Prediction equations are also empirically developed for computing the distance to max. ground level air concentration and for lateral particle variance to 2 miles. The measured vertical inhomogeneity of turbulence does not prevent a fair agreement between predicted and measured surface air concentrations when only source height wind data are used. Since the dispersion parameters were determined at the time of the diffusion experiments, the observed and computed results are not independent. Independent test data were not available for a more rigorous check of the method. (Author's abstr.)

3972. The Effect of Thermal Stratification on Turbulent Diffusion from a Continuous Fixed Source. S. K. KAO. *Tellus* (Stockholm) **12,** 359–63 (Nov. 1960).

The similarity principle is employed to determine the maximum velocity of the vertical propagation of a diffusing smoke flowing from a continuous fixed source in a stratified fluid. With the use of the velocity profile (Kao. J. Meteor. **16,** 497–503 (1959)) for a stratified fluid the profile of the boundaries of the smoke plume is evaluated numerically for various values of the stability parameter. An equation is given in the text. It is shown that the spreading of a smoke plume generally increases with increasing heat flux from the boundary surface. (Author's abstract—LC)

3973. Global Tropopause Maps by Satellite. D. C. VAN ORNUM. *J. Meteorol.* **18,** 234–41 (Apr. 1961).

The backscatter of a submicrosecond light pulse projected from a satellite is studied as a means of obtaining meteorological data. A time display of energy returned to the source will vary with atmospheric density, cloud top altitude, ozone layer, and occurrence and altitude of dust layers at the tropopause, in the stratosphere and in the vicinity of the 80-km. inversion. Of these possibilities, the measurement of height of selected air density levels in the vicinity of the tropopause can supply a max. of weather information for a min. of satellite power. (Author's abstr.)

ANALYSIS, DETECTION, MEASUREMENT, MEASUREMENT EQUIPMENT, MEASUREMENT METHOD, RESEARCH, SAMPLING, TECHNIQUES, TESTING

3974. Spectrophotometric Determination of Olefins. A. P. ALTSHULLER and S. F. SLEVA. *Anal. Chem.* **33,** 1413–20 (Sept. 1961).

Four carbon and higher molecular weight olefins can be determined quantitatively in the gas and liquid phases by reaction with *p*-dimethylaminobenzaldehyde in concentrated sulfuric acid, under appropriate conditions, and measurement of the absorbance at 500 mμ. With gaseous olefins the absorptivities are such that 0.1 ppm. or less can be determined. Interference by formaldehyde and excess aromatic hydrocarbons and phenols is appreciable, and simple methods for their removal are discussed. The method has been applied to the analysis of automobile exhaust and diluted irradiated exhaust mixtures. Liquid olefins have been studied under somewhat different reaction conditions; consequently, the positions, shapes, and intensities of the absorption bands differ somewhat. Although the work on liquid olefins was not as extensive as in the investigation of olefin gases, the results should have applicability in the identification and analysis of small quantities of liquid olefins. (Authors' abstr.)

3975. A Comparison of Particle Size Measurements. E. J. BAIER. *Amer. Ind. Hyg. Assoc. J.* **22,** 307–12 (Aug. 1961).

Particle size measurement is a major consideration for assessing the degree of hazard presented by airborne dust particulates. This paper describes a method of comparing investigators' techniques, by re-evaluation of the same slide by a single investigator and by comparing his technique with that of his colleagues. Particle size measurement, within a reasonable degree of accuracy, depends on practice, not on general experience in the field of industrial hygiene. In order to assess the degree of hazard of airborne silicosis producing dusts 3 factors are of importance, the free silica or in some cases, the silicate content; concentration, and particle size. Data concerning the reliability of particle size measurements are given.

3976. Sodium Diphenylaminesulfonate as an Analytical Reagent for Ozone. H. H. BOVEE and R. J. ROBINSON. *Anal. Chem.* **33,** 1115–18 (July 1961).

Sodium diphenylaminesulfonate, selected as an analytical reagent for the determination of ozone, reacts with ozone to form a turquoise blue-product with an absorption max. at 593 mμ. The reagent has been tested under various conditions to determine the effects of pH, temperature, concentration, type of sampling equipment, and rate of sample flow on its reaction efficiency. The effects of nitrogen dioxide, chlorine, hydrogen peroxide and other interferences have been investigated. An analytical procedure using 1% sodium diphenylaminesulfonate in 0.02% perchloric acid solution has been developed and tested for precision. It gave satisfactory results when field tested with ozone formed by inert gas shielded welding arcs and by an electrostatic precipitator. (Authors' abstr.)

3977. A Highly Sensitive Katharometer and Its Application to the Measurement of Ethylene and Other

Gases of Biological Importance. S. P. BURG and J. A. J. STOKWIJK. **J. Biochem. Microbiol. Technol. Eng.* (London) **1**, 245–59 (Nov. 1959).

The design and construction of a katharometer, which has been found to possess more than 100 times the sensitivity of more conventional thermal conductivity instruments, are discussed. By comparison with other types of gas analysers, the katharometer has the advantage of simplicity of design, and for this reason it is inexpensive to construct, is relatively trouble-free, and is long-lived in its operation. The major disadvantages of the available katharometers is that they can only detect quantities in excess of about 10^{-6} moles and that they are sensitive to temperature fluctuations. Recently instruments based on β-ray ionization and those based on ionization at high voltages have been described. These instruments are relatively independent of temperature and are several orders of magnitude more sensitive (10^{-12} and 10^{-11} to 10^{-13}, respectively) than the available katharometers. Presumably these new detectors will largely supplant the katharometer for use in high temperature gas chromatography. However, the katharometer may still be the most advantageous method for the detection of many biologically important substances which are volatile at room temperature. Included in this category are carbon monoxide, ethylene, various oxides of nitrogen, methane, ethane, oxygen, and other low molecular weight gases. Details of the construction of the katharometer, information on the chromatography column, conditions of maximum sensitivity, and results of the studies are discussed. (LC)

3978. Automatic Hydrocarbon Analyzer. L. W. COLEMAN. *Chem. Eng. Progr.* **57**, 55–8 (Apr. 1961).

Initial data indicate that a hydrogen flame ionization detector will provide frequent and adequate checks of contamination level. Figure 1 shows a schematic of the analyzer. For carrier gas, a stream is withdrawn from the low pressure column several plates above the entrance of the liquid and gas stream from the high pressure column. The chromatographic column consists of 8 ft. of $^1/_4$ in. aluminum tubing packed with 60-mesh activated silica gel. Temperatures of 125 to 145°F. have been satisfactory and the detector has been stable and flameouts are rare. A device selects and injects a 15 $cm.^3$ sample into the column at the rate of 8/hr. Lights indicate which is being analyzed. All lines are stainless steel, aluminum, or Tygon. When 300 v. are impressed across the hydrogen flame and a hydrocarbon is introduced into the flame ionization occurs with resultant flow of electrons. Recorder charts show that for practical purposes at low concentrations, the peak height is a direct function of the mol. or vol. concentration, then peak heights can be measured in terms of concentration using a small scale.

3979. The Estimation of Areas within Isopleths of Dosage Downwind of a Point Source. W. P. ELLIOTT and P. W. NICKOLA. *Amer. Ind. Hyg. Assoc. J.* **22**, 238–44 (Aug. 1961).

A method is presented for estimating the area enclosed by an isopleth of dosage downwind of a point source in the atmosphere. The method employs an empirical relationship between the area enclosed by a dosage isopleth and the value of the isopleth divided by the source strength and multiplied by wind speed, and is classified according to atmospheric stability. It is believed that results presented can serve as a guide in future studies. Further observations will be necessary in order to define the effects of differences in vegetation and terrain as well as deposition and stability at great distances upon the area dosage relationship.

3980. Analysis of Fuel Gases and Combustion Products. I. FELLS, T. J. HOWELLS, and M. A. PATRICK. *J. Inst. Fuel.* **34**, 283–90 (July 1961).

The factors affecting the efficiency and accuracy of the analysis of combustion gases by gas solid partition chromatography are discussed. The work was done using equipment incorporating a hydrogen microflame detector and later a katharometer detector. A study of the adsorptive powers of activated carbon, molecular sieve material, silica gel, and alumina in terms of gas chromatographic data has shown that these adsorbents can be used as column packing for the separation of gas mixtures at various temperatures. The effects of temperature, pressure, and flow-rate control, and the analysis of the chromatograms are also discussed. The results and conclusions given are intended as a guide to the selection of the best columns and conditions for a particular gas analysis. (Authors' abstr.)

3981. The Toxicity of Some Aliphatic Alcohols. Pt. II. E. V. HENSON. *J. Occupational Med.* **2**, 497–502 (Oct. 1960).

The saturated, open-chain, monochydric alcohols have been reviewed with reference to their general actions and chemistry. As a group they are anesthetic-narcotic agents similar to the other organic solvents, and by some measurements the intensity of this action increases progressively with the chain length. Among isomers, branching and locating the hydroxy radical in secondary and tertiary positions decreases the narcotic action when comparison is made with the normal compound. The important individual alcohols up to butanol are discussed in some detail. Although reports of serious methanol intoxications are no longer received from industry, it remains a potentially hazardous chemical. The absence of intoxications from the alcohols reflects the relatively low order of toxicity of this homologous series and indicates that adequate control over these solvents is being maintained. (LC)

3982. A Rapid Analytical Method for the Determination of Beryllium in Air Samples. R. A. HISER, H. M. DONALDSON, and C. W. SCHWENZFEIER. *Amer. Ind. Hyg. Assoc. J.* **22**, 280–5 (Aug. 1961).

Adoption of hygienic controls for airborne beryllium pointed up the need for a rapid analytical method for air samples. A method is described which consists of sample collection on Whatman 41 filter paper, ashing of the sample and subsequent conversion to beryllium fluoride. The formation of a lake with *p*-nitrophenylazoorcinol, and comparison of the Klett reading with a standard curve gives beryllium content. Samples containing between 5 and 45 μg. beryllium show a standard deviation of 8.4% and a 68% confidence level for values between $\pm$8.4% of true value or 95% confidence level for values falling within $\pm$16.8% of the true value. Such analytical accuracy is adequate for the inplant, monitoring of a beryllium facility.

3983. Ozone Analyzer Uses Radioactive Clathrate. C. O. HOMMEL, D. CHLECK, and F. J. BROUSAIDES. *Nucleonics* **19**, 94–102 (May 1961).

Ozone concentration can be measured by running a gas stream over a Kr^{85}-containing quinol clathrate and observing the amount of radioactivity released. A detector based on this principle and having many advantages over conventional ozone analyzers has been developed. With a specific activity of 1 c./gm. the instrument will detect ozone concentrations in the parts/10 b. range or smaller. Tests show that the instrument is fast, sensitive, and specific. When ozone strikes the reaction bed, krypton is released immediately and the counting rises sharply from background and then levels off at a constant value. Other gases detected in the lab. include sulfur dioxide, hydrogen sulfide, nitric oxide, nitrogen dioxide, chlorine, chlorine dioxide, and hydrazene. Further application of the principle will probably provide a useful tool in air pollution, process control, meteorology, and many other fields.

3984. [Determination of Lead in Air.] Bestimmung von Blei in Luft. G. KÖHNEN. *Staub* (Düsseldorf) **20**, 77–81 (Mar. 1960).

A new filter measuring instrument has been developed for the determination of suspended dust concentrations containing lead. An advantage of the analytical method with dithizone is described. The range of application is from 10–120 μg. lead with an average deviation of $\pm$1%. Smaller quantities of approx. 1 μg. lead may be determined with a somewhat greater deviation. (English summary cond.)

3985. [Rapid Method for Determination of Noxious Substances in Air. I. Zinc.] T. KOMODA, S. SUENAGA, and S. OSADA. **Kokuritsu Kōshu Eiseiin; Bull. Inst. Public Health* (Tokyo) **9**, 49–51 (Mar. 1960).

Several rapid methods suitable for field application have been developed for determination of noxious dusts and gases in the air of industrial environments. The present paper describes the method of zinc determination in the air. The sampling of air was run through a midget impinger loaded with a dilute solution of hydrochloric acid. Zinc caught in the solution was determined by the dithizon method (mixed color, titrimetrically). Two methods were used: the one being the ordinary extractive method; the other based on the reaction in a water-glycol monophase system. Both the methods have been demonstrated as applicable to solutions containing 5 to 500 μg. of zinc. **Ibid. II. [Fluorine (Fluoride).]** 52–3.—The present paper describes fluorine determination by the aluminum hematoxylin method for the purpose of field application. The sample air was run through a midget impinger loaded with 0.05 N sodium hydroxide solution. After absorption of fluoride, the solution was neutralized with diluted hydrochloric acid, then aluminum hematoxylin solution was added. Discoloring time was measured and the fluorine content was determined from a calibration curve. The calibration curve, in which discoloring times in seconds were plotted against fluorine concentrations, was made from the standard solutions containing 1 to 200 μg. of fluorine. This method was found to be little better in some respects than other ordinary methods of estimating fluorine but to be more suitable for field application.

Ibid. III. [Monochlorobenzene.] T. KOMODA and S. SUENAGA. 79–81 (June 1960).—The present paper describes the determination of monochlorobenzene in air by the sodium methylate method and the butanone method. The sodium methylate method for monochlorobenzene is a modification of the Schlechter-Haller's method for the colorimetric determination of chlorophenothane. The air was aspirated through a bubbler containing 5 c.c. of a mixture consisting of equal parts of fuming nitric acid and concentrated sulfuric acid, after which the solution was diluted with water and extracted with benzene. The benzene solution was washed with 5% sodium hydroxide solution and water and then dried with sodium sulfate anhydride. A sodium methylate methanol solution was added to an aliquot portion of the benzene solution, and the orange color developed was estimated electrophotometrically. The calibration curve of monochlorobenzene was made using nitromonochlorobenzene. Monochlorobenzene was also estimated by the ordinary butanone method for benzene. The shape of the absorption curve was similar to that of benzene but the color developed by monochlorobenzene was not as sensitive as that of benzene. **Ibid. IV. [Methyl Bromide and Phosgene.]** 138–40 (Sept. 1960).—The present paper describes the determination of methyl bromide and phosgene in the air. (1) Methyl bromide: The air was aspirated through two bubblers in series each containing 20 c.c. of a 0.5% alcoholic solution of sodium hydroxide. The solution in the two bubblers was poured into a stoppered flask, and after two hours of standing the liberated bromide in the solution was estimated by either of two methods. In the first method the sample solution was diluted with water, acidified with acetic acid, and titrated with 0.1 N silver nitrate using eosin solution as the indicator. In the second method, the chloride colorimetric method used by Bergman was applied. The sample solution was diluted with water, acidified with dilute nitric acid, and then a ferric ammonium sulfate-nitric acid solution and a mercuric thiocyanate alcoholic solution were added. The intensity of the color developed was estimated spectrophotometrically. (2) Phosgene: The principle of this method depends upon estimating the liberated iodine from a sodium iodide acetone solution by phosgene. The liberated iodine was either titrated with 0.001 N sodium arsenite solution after adding 0.001 N sodium bicarbonate solution, or is estimated colorimetrically. (Authors' English summaries, modified—LC)

3986. Use of Natural Airborne Radioactivity to Evaluate Filters for Alpha Air Sampling. C. L. LINDEKEN. *Amer. Ind. Hyg. Assoc. J.* **22,** 232–7 (Aug. 1961).

A method has been described using natural airborne radioactivity as a test aerosol, which is designed to compare the surface collection efficiency of filters used in α air sampling. Of the filters tested it appears that glass fiber is superior to HV-70. Then sheet polystyrene filters, although superior to glass in surface collection, have the dual disadvantage of high resistance to flow and handling difficulty due to shredding. Although the method lacks the accuracy desirable in a reference procedure for penetration measurements, it does provide a screening technique for new filters for which DOP data are lacking. Data are presented for Whatman 41 paper which show that the retention of particles in the size range associated with natural activity is quite velocity dependent. A max. occurs in the penetration-vs-velocity curve showing that both diffusion and impaction separation mechanisms are involved. At low velocity (= 5 fpm.), Whatman 41 retains natural activity with greater efficiency than 0.3 μ DOP particles. At 200 fpm., retentions for both particle size ranges are in close agreement. (Author's summary)

3987. Instrumentation for Olefin Analysis at Ambient Concentrations. S. W. NICKSIC and R. E. ROSTENBACH. *J. Air Poll. Control Assoc.* **11,** 417–20 (Sept. 1961).

This paper describes a bromination and coulometric system and the instruments developed to measure olefins in automobile exhaust and in the atmosphere. The concentration of olefins in automobile exhaust considered is over 100 ppm. while that in the atmosphere is usually less than 4 ppm. The method is based on the observation that the olefins, excluding ethylene, can be quantitatively brominated by passing a gas sample through a solution of appropriate composition, also on the principles of coulometric titration. Two olefin analyzers have been developed, 1 for atmospheric use and 1 for auto exhaust analysis. They are self contained portable instruments for automatic, continuous olefin analysis of a gas sample or stream.

3988. The Catalyzed Reaction of Oxygen with Sulfurous Acid and Its Effect on the Absorption of Oxygen and Sulfur Dioxide into Water. P. W. PRITCHETT. *Dissertation Abstr.* **21,** 2652 (1961).

The absorption of sulfur dioxide and oxygen into a manganese sulfate solution was investigated to observe the influence of the liquid phase oxidation reaction on the rates of absorption. This particular system is of potential importance in controlling air pollution. The investigation was carried out in 2 phases: a study of the kinetics of the liquid phase reaction and a study of the absorption with simultaneous reaction. The absorption experiment revealed the role of oxygen in the kinetics more clearly than was possible from the study of liquid phase kinetics alone. New theoretical developments include an exact analytic solution for absorption rates with simultaneous zero order reaction and a general approxn. method based on the steady state solution for absorption rates with simultaneous reaction. (Author's abstr. cond.)

3989. Comparative Concentration of Silica in Parent Material and in Airborne Particulate Matter. M. SHEINBAUM. *Amer. Ind. Hyg. Assoc. J.* **22,** 313–17 (Aug. 1961).

A 2nd progress report is presented on the relationship between the silica concentration of airborne particulate matter and the parent material from which it has been generated. Thirty airborne samples were collected using impingers or membrane filters, and parent materials were collected as grab or ledge samples. The Talvitie method for free silica determination was used for analysis of parent materials. Phase microscopy was used to analyze airborne particulate matter. Of the 30 sampling locations, 19 were located within 6 ft. of operations producing dust and 11 were located at greater distances. Data indicate that the concentration of free silica in the breathing zone of the operator is about the same as that in the parent material in cases where operators were within 6 ft. of the operation.

3990. [Influence of the Electrical Charge on the Coagulation of Dust.] Einfluss der elektrischen Aufladung auf die Koagulation von Staub. H. SCHNITZLER and J. SOMOLYAI. *Staub* (Düsseldorf) **21,** 241–6 (June 1961).

This article describes a process which measures the relationship between electrical charge and coagulation of a dust cloud under climatic conditions that are maintained constant. The distribution of falling velocity is measured by means of a recording electrical microbalance of the Gast type. At the same time the state of charge of the entrained dust is recorded separately by positive and negative charges by using a double condenser and 2 electrometer amplifiers. Some current qualitative results are reported. (English summary cond.)

3991. [A Comparison of Several Methods of Determining Dust Contamination.] Srovnání některých metod k stanovení prašeosti J. ŠIMEČEK and L. OPPL. Pracovní lékařství (Prague) **10,** 485–91 (Oct. 1958).

Data obtained by the quantitative method, after collection of samples on a membrane filter, were compared with data obtained by calculation of the number of particles in similar samplings collected with the electroprecipitator, with an impinger, and with the Bausch and Lomb conimeter. The results were computed by the group method and were used for the evaluation of the individual methods of estimating the amount of dust and for assessing the maximal permissible concentration of dust in the atmosphere given by the number of particles which correspond to the currently accepted standards determined by weighing. Current regulations set a standard of 2 mg./m.^{3} of deposited matter by weight, which is estimated to contain 150 particles/cm.^{3}. The same amount of dust was found by the electroprecipitator method to contain an average of 1250 particles/cm.^{3}; with the impinger 1300 particles; and with the conimeter, 85 particles. In a similar comparison of 30 mg./m.^{3} of dust and a particle count of 1000 particles/cm.^{3}, these figures were 12,500, 18,000 and 850 particles/cm.^{3} respectively. (LC)

3992. A New Field Method for the Determination of Organolead Compounds in Air. L. J. SNYDER and S. R. HENDERSON. *Anal. Chem.* **33,** 1175–80 (Aug. 1961).

A simplified field method permits the rapid determination of several organolead compounds in air. It is superior to methods previously described for the determination of tetraethyllead in air. The method utilizes as a scrubber a small disposable glass tube containing iodine crystals supported by 2 glass wool plugs. Lead is removed from the scrubber by an acidic potassium iodide solution and is measured by a colorimetric dithizone method. The scrubber is also effective in collecting some organometallic compounds of metals other than lead. Data are presented to show relative reaction rates and intermediate products obtained from reacting tetraorganolead compounds with aqueous iodine in conventional scrubbers. (Authors' abstr.)

3993. **[Determination of the Size of Industrial Aerosol Particles in the Urban Atmosphere.]** Určovani velikosti částic průmyslového aerosolu v městskem ovzduší. K. ŠPURNY, M. POLYDOROVA, J. PIXOVÁ, and P. BARTL. *Cesk. hyg.* (Prague) **5,** (8) 498–502 (1960).

The authors describe a method of withdrawing aerosol samples from the urban atmosphere in order to determine the size and shape of the aerosol particles. The method consists of a combination of the method of diffuse "trapping" on fibrous crystals and the sedimentation method; it is much simpler than "trapping" by a thermoprecipitator or an electrostatic precipitator. It is sufficient to put a weathercock with sedimentation slides (glass plates) with a microgrid at the site where the measurements are taken, to expose it for several hours or several days, and then without any further processing to investigate the samples obtained under an optical or electron microscope. Also the shape of the particles and their approximate chemical composition can be determined by this method. (Authors' English summary—LC)

3994. **[Determination of Nitrogen Oxides in Air. Pt. I.]** O. TADA. *J. Sci. Labour* (Rodo kagaku) (Tokyo) **37,** 8–15 (Jan. 1961).

The method of determination of NO_2 and NO_3 was examined and the conditions of oxidation of NO to NO_2 or NO_3 were studied. Determinations of NO, $NO_2(N_2O_4)$, and $HNO_3(N_2O_5)$ by methods A, B, and C were carried out using several samples. In this paper the procedure of the determination of nitrogen oxides is described and the instances of estimation in various exhaust gases will be reported in a later paper. Method A: NO_2 in air was aspirated through a midget bubbler containing 3 c.c. of absorbing fluid (0.1 N NaOH, 1 vol.: C_2H_5OH, 2 vol.) at a rate of 1 dl. of air per 3 minutes. The absorbed NO_2($^1/_2$ NO_2) was determined colorimetrically with Griess-Ilosvay reagent as modified by Jacobs. The collecting efficiency for NO_2 was greater than 90% by the above-mentioned procedure. 0.1 N NaOH solution was unsuitable as absorbing fluid because the collecting efficiency for NO_2 is lower and inconstant. Method B: Mixtures of NO and NO_2 in air were collected in a syringe or gas-collecting tube in which 5 c.c. or more of absorbing fluid (0.1 N NaOH, 1 vol.; C_2H_5OH, 2 vol.) was injected, and the resulting mixture shaken for 5 minutes. After standing for 24 hours NO was oxidized to form $^1/_2$ NO_2 in the absorbing fluid. NO_2 in 3 c.c. of absorbing fluid in a test tube was determined colorimetrically with Griess-Ilosvay reagent, modified by Jacobs. The value obtained by this method was calculated to (NO_2 + NO) ppm. Method C: Mixtures of NO, NO_2, and HNO_3 in air were collected in a syringe or gas-collecting tube in which 6 c.c. or more of absorbing fluid (0.02 N $KMnO_4$, 1 vol.: 0.4 N KOH, 1 vol.) was injected in it and shaken for 5 minutes. On standing for 5 hours NO, NO_2, and HNO_3 were oxidized to form NO_3 in the absorbing fluid. NO_3 in 5 c.c. of absorbing fluid in a test tube was determined after reduction of $KMnO_4$ with ammonium oxalate. NO_3 in the solution was reduced to NO_2 with 0.3 g. of zinc powder at pH 5.4–5.6 and determined colorimetrically with Griess-Ilosvay reagent as modified by Saltzman. The values obtained by this method are calculated to (NO + NO_2 + HNO_3) ppm. (Author's English summary, modified—LC)

AREA MEASUREMENT, SURVEYS

3995. **[Analysis of the Health Condition of Children Living in the Vicinity of Aluminum Works.]** Hlbkový rozbor zdravotného stavu detí v sídliskách z okolia závodu na výrobu hliníka. G. BALAZOVA, L. BALAŽOVJECHOVÁ, and V. KIRILČUKOVÁ. *Cesk. hyg.* (Prague) **5,** (10) 573–9 (1960).

Studies were made of the state of health of children living in a village in the vicinity of an aluminum plant, and in a control village, including estimations of the hemoglobin percentage, the erythrocyte and leukocyte count, the differential blood count, the amount of fluorides eliminated in the urine, and the general condition of health. In the group of children of the affected village, radiographs of the bones and examinations of the teeth were also performed. For the group from the air-polluted area, the average percentage of hemoglobin was 62.8% (6–8 year old) and 69.5% (9–11 year old), as compared with 70.9 and 72.2% respectively in the group from the control village. The average erythrocyte count in children of the affected village was 3,958,000 (6–8 year old) and 4,208,000 (9–11) as compared with 3,741,000 (6–8) and 4,208,000 (9–11) in the control group. No substantial differences between the groups were found in the values of segmented and nonsegmented neutrophils, eosinophils, basophils, lymphocytes, and monocyte counts. The average level of fluorides eliminated in the urine was 0.91 mg./l. in children of the polluted area as compared with 0.48 mg./l. in those of the control village. Evaluation of subjective troubles and objective symptoms showed no perceptible differences between children of the affected and those of the control village. Radiographs of bones of children of the affected village showed no changes which could be suggestive of pathological and significant fluorosis. (Authors' English summary, modified—LC)

3996. **Some Aspects of the History of Anti-Pollution Legislation in England, 1819–1954.** A. BECK. *J. Hist. Med.* **14,** 475–89 (1959).

When air pollution and filth were suspected as contributing factors in the rising death rate and the increasing frequency of epidemic diseases, a Select Committee of Parliament was appointed which published its findings in 1819 and 1820. In their report the members of the Committee seemed, surprisingly, to be convinced that the people had a right to be protected from the evil effects of smoke nuisances. However, a report of the Poor Law Board in 1843 voiced its opinion that smoke prevention was possible and should not be too costly but also raised the question whether the introduction of smoke-consuming mechanical devices might well interfere with the interests of the proprietors of furnaces. A third report in 1845 and a new investigation in 1862 both stressed the ineffectiveness of anti-pollution legislation. The Nuisance Removal Act of 1856 gave inspectors of nuisances only limited rights of entry. In contrast to these 19th century reports on air pollution is the 1954 report which starts with an assumption that pollution is a social evil and that a national effort to rid the country of the evil would be costly, but that government, local authorities, industry, and householders alike would have to pay the cost for prevention. In the 19th century the reports were written with an eye to the manufacturers and improvements were suggested in an apologetic way. In the 20th century the committee in charge of the report was primarily concerned with the health and welfare of the people. And finally, medicine and public health had progressed sufficiently by the end of the 19th century to lend active support to the fight against air pollution. (LC)

3997. **Air Pollution Potential East of the Rocky Mountains. Fall 1959.** C. M. BOETTGER. *Bull. Amer. Meteorol. Soc.* **42,** 615–20 (Sept. 1961).

The weather over the eastern $^2/_3$ of the U. S. was monitored, and air pollution potential forecasts were made and disseminated to affected cities. The results of the experiment strengthen the validity of the criteria as indicators of prolonged periods of high air pollution potential. The frequency of these conditions is low and limited by season and location. Results of soiling index data and special control sampling, however, illustrate that isolated days of high pollution (not prolonged periods) can occur without the light upper wind requirement or a previous stagnant day. Therefore, any operational air pollution forecast program should not be limited to the forecast criteria, as some serious air pollution problems may arise during relatively short periods of 1 or 2 days when the surface wind speeds and atmospheric stability combined with local topography are conducive to poor air quality. Continuous efforts are being made to improve the forecast methodology.

3998. **The Unemployment Problems Associated with Chronic Bronchitis in East London.** M. CAPLIN and C. P. SILVER. *Brit. J. Diseases Chest* **54,** 297–307 (Oct. 1960).

The Hackney Employment Exchange serves both the boroughs of Hackney and Stoke Newington. The Borough of Hackney lies in the northeastern part of the County of London. Its southern part is very highly industrialized with clothing and furniture making being the important local industries. The two boroughs have a total population of approximately 214,000 and the total number of registered disabled males in April 1958 was 2614 of whom 197 or 7.6% were suffering from bronchiectases, bronchitis, or emphysema. The comparable percentage for the country as a whole was 6.4%. In the current study, 83 males (aged 40–64) with chronic bronchitis were questioned about their employment histories. Only 30% had been registered as disabled persons at any time and only 17% were on the register at the time of this survey. Registration was more common among younger bronchitics and among those in social classes IV and V (partly skilled and unskilled workers). Advancing age and lack of skill were in every way unfavorable to the employment of the bronchitics. (LC)

3999. **[Pollution by Carbon Monoxide of Urban Air in Relation to Traffic of Vehicles with Combustion Motors.]** Inquinamento da CO dell'aria urbana, in rapporto alla circolazione dei veicoli con motore a scoppio. G. DI LULLO. *Nuovi ann. igiene e microbiol.* (Rome) **11,** 141–53 (Mar.-Apr. 1960).

Studies were made of the concentration of CO at various locations in the city of Naples. It was found that at three lo-

cations with heavy traffic and in one where it was extremely heavy, the concentrations ranged from a trace to 150 ppm. In a series of determinations at 19 different locations in the vehicular traffic tunnels of the city there were a few observations of no CO present but mostly the concentrations ranged from 50 to a high (in 3 locations) of 200 ppm. Quoting from an earlier paper by a co-worker, the author gives CO concentration ranges of 10–300 ppm. for New York City; 10–60 for Paris; 0–200 for Berlin; 4–40 for Dresden; and 1–200 for Budapest. (LC)

4000. [The "Clean Air" Problem, with Special Regard to Iron Works, Particularly to Steel Plants. IV. Maintaining the Cleanliness of the Air, A Desire and Problem of Our Day.] Das Problem "Reinhaltung der Luft" unter besondered Berücksichtigung der Eisenhütten-, insbesondere Stahlwerks-betriebe, IV. Reinhaltung der Luft, ein Anliegen und Problem unserer Tage. K. GUTHMANN. *Radex Rundschau* (Radenthein) **No. 1,** 449–84 (Feb. 1961).

After a historic review of the question of air contamination by smoke and gases, the legal regulations of this problem in the USA, France, the Netherlands, Soviet Russia, Great Britain, Austria, Belgium, Italy, Switzerland, Sweden, and the German Republic are discussed. Particular reference is made to the German law effective since June 1, 1960, against air pollution with the new regulations regarding protection of the neighborhood, control measures, technical rules, etc., and to the reports of the VDI committee for preventing air pollution. Furthermore, the present study deals with the present state of dust removal and gas purifying plants in steel mills, namely, purifying of blast furnace gas and of waste gases from sintering plants, the flue gases from open hearth furnaces and in particular of those operated with the addition of oxygen, waste gases of Thomas converters, and the abolition of the brown smoke from smelters using the LD [Linz-Donawitz] process and from a small foundry Bessemer converter. (Author's summary, modified—LC)

4001. Dispersion and Effects of Airborne Fluorides in Central Florida. E. R. HENDRICKSON. *J. Air Poll. Control Assoc.* **11,** 220–5, 232 (May 1961).

In applying the theoretical consideration to actual plant production, a number of different procedures are used to produce triple superphosphate. In nearly all of the processes, phosphoric acid is manufactured by reacting sulfuric acid with the phosphate rock, filtering the phosphoric acid from the calcium sulfate, and concentrating the phosphoric acid by evaporation. The sources and forms of fluorides released during the manufacturing are reported. In the central Florida area, adverse effects from fluorides have been alleged on vegetation, domestic animals, and human health. Fluorides in gaseous form particularly when present as HF, SiF_4, or H_2SiF_6 are highly toxic to growing vegetation, to humans, and to animals when present in sufficient concentration. During a study made over a period of a yr. using static samplers the extent of the affected area and the relative ground-level concentrations of fluorides were determined, and a comparison made of the exposure in 1 area to that in another. Monthly maps showing fluoride isopleths are available for each month of 1959 and for each month of the 1st quarter of 1960.

4002. The Role of Czechoslovak Medical Geography in the Study of Air, Water, and Soil Pollution. U. S. Joint Publications Research Service. JPRS: 5422. Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. Apr. 10, 1961. 7 pp. Transl. in part of: Article by J. KRAL. *Geografický Časopis* (Bratislava) 12, 247–52 (Sept.–Dec. 1960).

The author discusses some of the early contributions by Czechoslovakian scientists to problems of air pollution, and mentions his own study of the degree of air pollution in Greater Prague, in 1951 and 1952. A Committee on Emissions was established by the Czechoslovak Academy of Sciences to study problems of air pollution and, in 1958 and 1959, this group determined the current conditions of air pollution in Czechoslovakia and outlined further research in this field for the State Plan of Standard Scientific Research Projects. In 1959 the Council of the Central National Committee of the City of Prague reached similar conclusions on the seriousness of air pollution over Prague, and discussed the possibilities of its eradication. The author expresses his concern that the studies undertaken have not employed the skills of a medical geographer since he feels that such research should be based on the study of a geographical area as it is being contaminated by man's intervention as a geographical agent. For this reason the author has attempted to establish the Czechoslovak Committee for Medical Geography. The contamination of regions like those of Ústi and Ostrava, which rank among the most polluted in the world, is partly due to their great density of population and industrialization, but also to their unfortunate geographical position and geographical surroundings. A pollution count carried out in 1954–56 indicated an area in Ostrava as having the highest maximum monthly discharge, amounting to 71,060 quintal [7832.9 ton]/km.²/year. The seriousness of air pollution in various areas is being indicated by the dying out of some of the more susceptible fauna and flora: bees, hops, and the common fir tree. (LC)

4003. [Air Pollution and Sunlight in the Industrial Region of Upper Silesia.] Luftverunreinigung und Sunnenstrahlung in Oberschlesischen Industriegebiet. J. PASZYNSKI. *Időjárás* (Budapest) **64,** (3) 137–43 (May-June 1960).

The degree of atmospheric pollution in relation to the degree of sunlight obtaining in the heavily industrialized region of Upper Silesia, is discussed. On the basis of these studies the variation of the obscuring or extinction of sunlight was found to be parallel to the variation of the quantity of atmospheric fumes and smoke particles, the light being increasingly obscured as the atmospheric pollution was increased [no statistics given]. The author states that the role of atmospheric pollution of the industrial region of Upper Silesia, when compared with the equally-industrialized areas around the cities of Chorzów and Katowice [Stalinogród], was lessened by the forested areas around that region as well as by the predominantly favorable wind directions which prevail. Measurements of sunlight were made with the use of an actinometer of the Moll-Gorczynski type. Derivations of the various equations are given in the text. By employing a red filter it was possible to obtain also the related values of both the short and red ranges of the light spectrum. (LC)

4004. [Problems of Air and Water Contamination in Czechoslovakia.] B. POUR. U. S. Joint Publications Research Service. JPRS: 4556, April 24, 1961. 4 pp. Available from Office of Technical Services, U. S. Department of Commerce, Washington, D. C. Transl. from: Priemysel a krasa okol nas. **Príroda a spoločnosť* (Bratislava) **10,** 8–11 (Jan. 1961).

The degree of pollution of Greater Prague in 1939 was indicated by the deposition of approximately 90 metric tons/km.² of particulate matter, which increased to about 200 tons in 1949, and is at present about 500 tons. In the whole industrial area of Liben and Vysocany it averaged 2000 tons a year. The surface of the area (126 km.²) of Velka Ostrava was covered, in 1956, by 888 tons/km.² and in 1958 by 1150 tons/km.² The most heavily contaminated area is in the vicinity of the large power stations in Northwestern Bohemia where the average annual deposit is 1467–4100 tons/km.². In addition there is contamination, especially from chemical-processing, by sulfur dioxide, chlorine, hydrogen sulfide, and other gases. A steam power station with a heavy output may produce as much as 5000 tons of slag and ashes as a byproduct. Storage of these piles of refuse disfigure the landscape and, in addition, use land which could be otherwise productive. As measures of control of pollution there are now some 30 regulations, valid for the whole territory of the state, which relate to the purity of water, air, and nature. All these decrees are only partial, lack interrelation, and do not solve the problem as a whole. The basic document of this legislation is the Resolution of the Central Committee of the Communist Party of Czechoslovakia embodied in State Resolution No. 177 of March 1959. To provide the government with more power and influence in coordination of the partial decisions and control of fulfilling specific tasks, various laws are being prepared. Within the wide scope of these efforts Law No. 101 of July 11, 1960, is the first important result. The recently announced Government action on the cleanliness of air was taken under the decree of October 21, 1960 on using material sanctions when excessive contamination of air is observed. The control will, therefore, be in charge of national assemblies. (LC)

4005. Relation of Benzene Soluble Organic Matter to Suspended Particulate Matter in the Atmosphere. E. C. TABOR and D. H. FAIR. *J. Air Poll. Control Assoc.* **11,** 403–7, 427 (Sept. 1961).

The relationship between benzene soluble organic matter and suspended particulate matter in air particulate samples collected at 144 urban and 38 nonurban stations of the Natl. Air Sampling network, during 1957–58 have been compared using arithmetic means, geometric means, and standard geometric deviations as a basis for the comparison. The national arithmetic mean value of the benzene soluble organic to suspended particulate ratio was 0.082 for the urban and 0.084 for the nonurban stations, and the respective geometric mean values were 0.074 and 0.066. Standard geometric deviations of 1.62 for urban and 1.98 for nonurban stations, indicate a greater range of ratio values for nonurban stations. (Authors' summary)

BOOKS, MANUALS, SELECTED PUBLICATIONS, SPECIFICATIONS, STANDARDS, TECHNICAL REPORTS

4006. [Introduction to Particle Size Measurement; Particle Size Analysis; Characteristics of Particle Structure; Surface Determination; Sampling.] Einführung in die Korngrössenmesstechnik; Korngrössenanalyse, Kennzeichnung von Körnungen, Oberflachenbestimmung, Probenahme. W. BATEL. Berlin. Springer-Verlag, 1960. 156 pp.

The table of contents lists an Introduction; Diagrammatic Presentation and Characteristics of Particle Size Distribution; Sampling; Particle Size Analysis; Methods of Direct Measurement of the Surface Configuration and other Aspects of Granular Substances; Some Examples of the Use of Particle Analysis. Following the table of contents there is a glossary of the terms used. Each chapter has a short bibliography. There are both an author and a subject index. (LC)

4007. [Methods of Determination of Harmful Substances in the Air and Other Media. (Practical Handbook) Pt. I.] Metody opredeleniîa vrednykh veshchestv v vodstvo). Chast' I. M. S. BYKHOVSKAÎA, S. L. GINSBURG, and O. D. KHALIZOVA. Medgiz, Moscow, 1960. 312 pp.

The various methods for determining the harmful substances in the atmosphere and other media are discussed under the following subject headings: Air sampling; Methods of analysis; Halogens and hydrogen halides; Nitrogen compounds; Ozone and hydrogen oxides; Sulfur and its compounds; Selenium, tellurium, arsenic, phosphorus, antimony and their compounds; Silicon, boron, and their compounds; Metal and metallorganic compounds; and Industrial dusts. (LC)

4008. The Air We Breathe; A Study of Man and His Environment. Edited by S. M. FARBER and R. H. L. WILSON in collaboration with J. R. GOLDSMITH and N. PACE. Springfield, Ill., C. C Thomas, 1961. 414 pp.

This book is a record of the papers presented and the discussion panels held at a recent international symposium (Jan. 16–18, 1960), at the University of California Medical Center at San Francisco, under the same title as that for this monograph. A total of 31 internationally recognized specialists in the various aspects of air pollution contributed to the 25 chapters of this volume. The information is assembled in sections entitled: The "Normal" Atmosphere and Its Variation; The Air Pollution Problem of Industry; Urban Living and Air Pollution; Smog and Fog; Specific Problems; and Lung Cancer. One chapter in each of these 5 sections is devoted to the discussions, in a conversational format, of a Panel considering a subject pertinent to the section. The volume contains an author index and also a short subject index. (LC)

4009. Recommendations for an Industry-Wide Oil Burner Research Program. Summary Report. D. W. LOCKLIN. Battelle Memorial Inst., Columbus, Ohio. 1960. 149 pp.

Contents: I. Summary. II. Appraisal of research and development needs: Industry background and needs. Scope and plan of research study. Status of present research and development activity. Research and development needs. Recommended research and developed priorities. Stimulation of research and development. Acknowledgment. References. Appendix. A. Literature review and technical information sources. B. Discussion group meetings. This study covers as an initial part of a broad effort to improve oil-heating markets, the Fuel Oil Comm. of the API appointed a subcommittee to develop a research plan devoted to improving existing fuel-oil-burning equipment and developing new uses for fuel oil. The recommendations resulting from this study are intended to form the basis for planning a coordinated industry program of research and development directed toward this end.

4010. Exhaust Contamination in Passenger Cars. A. H. ROSE, JR., R. C. STAHMAN, and H. J. R. STEVENSON. U. S. Department of Health, Education, and Welfare. Public Health Service. Robert A. Taft Sanitary Engineering Center. Technical Rept. **A61-2.** Feb. 1961. 9 pp.

A preliminary test program has been made to investigate some basic factors affecting the concentration of exhaust gas inducted into the passenger compartment of an automobile by the forced ventilation system. With the small number of tests run, it is not intended that the values developed be interpreted as statistically "normal" but rather as an indication of possible levels and trends. Tests were run on grouped moving vehicles and on grouped stationary vehicles to simulate heavy traffic conditions. Exhaust concentrations in the passenger compartment of vehicles under moving traffic conditions were slightly above the background curbside levels. Stationary traffic conditions with vehicles grouped at average intervals produced marked increase in exhaust concentrations with the highest recorded at 0.8% (370 ppm CO) of the raw exhaust value. In moving vehicles, the highest value recorded was 0.04% (20 ppm CO) above the curbside level. The location of the forced ventilator inlet was shown to exert a significant effect on the exhaust concentration in the vehicle passenger compartment. Front inlets as contrasted to cowl and side inlets consistently gave higher values. Stability and movement of the air mass circulating around the stationary vehicles was the second factor exerting a significant influence on passenger compartment concentration. No significant effect was indicated by the differences in exhaust tailpipe location as used in present day automobiles. A vertical exhaust system (extended to car-top level) gave essentially zero passenger compartment concentration. (Authors' summary—LC)

4011. Experimental Investigation of the Carbon Dioxide Content of the Air and an Analysis of Its Gaseous and Colloidal Phases. G. STETTER. Physikalisches Institut der Universität Wien. Vienna, Austria. 1960. 61 pp. Available for $3.90 as microfilm or $10.80 as photocopy, as PB 154–155 from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

This is the final technical report of research which was carried out under the sponsorship of a U. S. Government contract. The final report of 1959 had been devoted to proving the presence of a colloidal phase of CO_2, to discussing the changes in content of CO_2 depending upon changes in weather conditions, and to the behavior of synthetic mixtures of gases (calibration-gas) and of compressed air. Emphasis in the current work was given to the elimination and identification of the light-sensitive nuclei or substance(s) after experiments with physical methods (URAS and the Komptron-ring-balance) were carried out, which also were used to show the presence and structure of the colloid. In chemical tests, separations were undertaken with filters and later separations with the thermal-sediment-tube. Later, all substances so separated were identified. This information is discussed within the following table of contents: Dark-tests with atmospheric air, compressed air, and calibration-gas; Comparative tests with the URAS; Tests with different types of filters; Theory of, description of, and tests with, the thermal-sediment-tube; Identification of substances; Optical method; Tests with the URAS; Tests with the Komptron-ring-balance; and Discussion of the results and implication of future work. (LC)

4012. Air Monitoring and Sampling Networks; Proceedings of the 1959 Seminar. Technical Rept. **A60-3.** Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio. U. S. Department of Health, Education, and Welfare; Public Health Service. 1960. 135 pp.

This publication is devoted to the proceedings of a seminar on air monitoring and sampling networks, held at the Robert A. Taft Sanitary Engineering Center on November 23–24, 1959. The seminar was sponsored by the National Air Sampling Network of the Center. The information is presented, within a conversational format, under the following headings: Introduction; Seminar and Network Objectives; National Networks; State and Local Networks; Selection of Sampling Sites; Equipping Sampling Stations; Operation of Stations; Laboratory Support; Data Handling and Reporting; Data Analysis; Use of Data; and Interchange and Release of Data. (LC)

4013. Air Pollution; Effects Reported by California Residents. State of California, Department of Health, 2151 Berkeley Way, Berkeley 4, Calif. [1960] 56 pp.

The information of this report was acquired in connection with the Special Morbidity Survey of 1956. It was a household sample survey similar to the California Health Survey of 1954–55, in that it was based upon household sampling and personal interview techniques. The sample was a probability sample consisting of 3545 households selected to be representative of all people in the State in a ratio of 1 to 1155. The table of contents of the report lists an Introduction; Summary of Major Findings; Importance of the Air Pollution Problem in California; Seasonal Pattern in Air Pollution (Metropolitan vs Non-metropolitan Air Pollution); Characteristics of the State Sample (Personal, Socio-economic, Health Status); Air Pollution as a Disruptive Element in Community Life (Effects of Air Pollution on Community Stability, on Community Satisfaction, and on the Working Population; and Transportation Patterns Related to Air Pollution); and Effects of Air Pollution on Persons with Selected Conditions. In the summary it is stated that data resulting from the California Health Survey show that 45% of the adult population of the State was bothered by air pollution either at home, at work, or

both. Eye and nasal irritation were the most frequently reported effects. Persons with chronic respiratory conditions were more likely to report sensitivity to the effects of air pollution. Some Californians had given serious thought to moving or to changing jobs because of air pollution, while others had already moved one or more times because of air pollution, chiefly from areas in Los Angeles County. The most serious and extensive complaints concerning air pollution came from Los Angeles County, but it should be noted that California's air pollution problem is not limited to Los Angeles County. The number and kinds of air pollutants are increasing in other metropolitan and urban areas in the State. People are becoming aware of unpleasant odors and are beginning to experience eye irritation and other types of disturbance. (LC)

EFFECTS OF AIR POLLUTION

4014. Historoentgenography—a New Examination Procedure in Pneumoconiosis and Intoxication by Heavy Metals. L. BREITENECKER. 675–6. In: *Proc. Thirteenth International Congress on Occupational Health*, New York, July 25–9, 1960. New York, Book Craftsmen Assoc., Inc.

Historoentgenography, or microradiography with soft x-rays, permits localization of delicate dust particles in lung tissue and evaluation of their destructive action at the exact site without alteration of the histological section. Thin histological sections are mounted, after deparaffinization, on a flat metal ring which is covered by a thin membrane. These sections, after drying, are placed on a fine grain film, and a roentgen contact negative is produced. This is then enlarged microphotographically and becomes a positive copy. After this procedure the tissue section is removed from the membrane, stained, and microphotographed. This allows for direct comparison of pictures of the same section which permits localization of the foreign bodies in the section. It is understandable that only this method allows comparison of the roentgenogram and the light microscopic photograph, because, due to the minuteness of the dust particles (0.1–0.5 μ), even the next serial section will show other particles in another location. Pure carbon particles show only slightly more absorption of x-rays than the tissue itself, white quartz particles and calcium absorb x-rays to such a degree that sharply defined images are produced. After decalcification with HCl and subsequent repeat contact historoentgenography, the remaining particles can be considered to be quartz. Research studies are currently being carried out attempting to make it possible to analyze mixtures of elements historoentgenologically when the atomic weights are nearly the same. Another research project is under way attempting to clarify differences in absorption in various parts of the silicotic nodules which are possibly due to impregnation of the connective tissue with colloidal solutions of silica or alteration of proteins. **Ibid. Iron-Coated Carbon Particles in the Human Lung.** A. F. LIBER. 738–40.—The finding of numbers of black-cored pseudo-asbestosis bodies in the lungs of several patients led to the examination of lung tissue following autopsy of 100 unselected cases to act as a control group. In this control group were also found the two types of particles: segmented bodies similar to asbestosis bodies, and the continuous bodies with their continuous coating. Both contained black cores and have been designated collectively as iron-coated carbon particles. The particles were monorefringent and equally visible in stained and unstained sections. The site has been exclusively the lung. The particles have not been found in the usual or less usual sites of anthracosis, in tubercles, or in silicotic foci. As far as could be determined by the light microscopic, they have always been extracellular in location. Segmented bodies were found in 8 cases including 3 coal miners and a hod carrier in a small mining community. The other 4 had moderate anthracosis although the occupations of 3 of these were unrelated to coal and that of 1 was unknown. Of the 8 cases, 2 were in the large control group. The incidence of continuous bodies was much higher than that of segmented ones. A total of 27 were found of which 18 were in the control group. No occupational correlation could be found. Examination of lung sections of an additional group of children from birth to 15 years, revealed none of the particles but carbon deposits were slight and present only in the older children. It has been suggested that soot is often the nucleus of these bodies. The iron-coated carbon particles are readily differentiated from iron and carbon particles commonly seen in macrophages, where they are interspersed, but the one does not enclose the other. This suggests a noncellular mechanism of formation of the iron-coated carbon particles and is in keeping with a hypothesis that particles penetrate the alveolar wall and reach the interstitium independently of cells. **Ibid. The Effect of Dietary Metal Ions on Carbon Disulfide Toxicity.** L. D. SCHEEL, R. G. KEENAN, J. T. MOUNTAIN, J. HOLTZ, and R. KILLENS. 783–5.—One group of 12 rabbits was maintained on a regular diet of rabbit pellets and another group of 12 animals on this diet plus 4% of Philips and Hart salt mixture. Both groups were exposed to CS_2 vapor in air at a level of 750 $\pm$ 100 ppm for 6 hours daily, 5 days a week, for a period of 52 days. Such an exposure had been found previously to be sufficient to cause obvious signs of injury to the voluntary movement of the rear legs. From the results of the experiment it was concluded that addition of the salt mixture delayed the onset of injury caused by exposure to CS_2. The effect of the dietary salts was correlated with body weight gain and changes in Cu and Zn content of the tissues. In the group of animals fed only pellets, not only did they fail to gain body weight but gradually lost weight while those animals fed the pellet and salt were able to maintain the body weight for 26 days of the exposure time. The loss of Zn in muscle, spleen, and adrenals shown by animals on a diet of pellets compared with the loss of Zn in only the muscle observed in animals on the added-salt diet, supports the observations for a sustained weight and less severe signs of injury observed in the rabbits on the added-salt diet. The finding of greater than normal amounts of Cu and Zn in the exposed animal tissues is further evidence that the CS_2 reacts with the tissue components to chelating groups which combine with the divalent ions and hold them in the tissues in a bound and metabolically inactive form. The observations reported provide definite evidence that CS_2 toxicity interferes with the inorganic metabolism at a cellular level. **Ibid. Effect of Fibrous and Amorphous Asbestos on the Collagen Content in the Lungs of Guinea Pigs. (Preliminary Rept.).** K. SZYMCZYKIEWICZ and E. WIECEK. 801–5.—One group of 12 guinea pigs was given intratracheal injections of 40 mg. of fibrous asbestos dust in a physiological saline suspension; a second group was given similar doses of amorphous asbestos dust; five guinea pigs served as controls. Animals from each group were killed at intervals of several days from 7 to 90 days after the dust administration. The SiO_2 content of both the blood and the dried lung tissues was determined as well as the collagen content of the latter. The SiO_2 levels in the blood serum of both experimental groups were significantly higher than the controls, and in the first 3 weeks the quantitative difference in the two experimental groups was significantly different. At the period of 90 days following injection the levels were about 42 mg.% for the group given amorphous dust, about 35 mg.% for the fibrous dusts, and about 22 mg.% for the controls. It was assumed, based partially on *in vitro* studies, that the dust solubility in the lungs and the SiO_2 transfer into the blood was significantly greater for the amorphous dusts. An increase in collagen content of the lungs over that of the control animals was found after 30 days. After 60 days a statistically significant increase was found in the group given fibrous asbestos over that given amorphous asbestos. At that time the collagen content in the dry pulmonary tissue was 15.50% in the fibrous group and 12.50% in the amorphous group, while the control group levels remained at 8.28%. Histopathological examinations of the lung tissues indicated a much greater and more extensive alteration in the peribronchial tissues of the group receiving fibrous dust and that these alterations tended to increase during the course of the experiment. In studies of the SiO_2 content of the lungs, the greater velocity of elimination from the lungs of amorphous in comparison with fibrous asbestos is probably one of the factors causing its lesser properties of biological reactions. This would be confirmed by the differences in amounts of collagen determined in the lungs of guinea pigs. **Ibid. The Activity of Silicates on the Evolution of Silicosis.** R. TRIPSA. 806–10—This study describes experiments made with some of the most frequently encountered silicates (kaolin, feldspar, white mica, montmorillonite, and loess) in a relatively pure state or when mixed with silica. The material was administered in doses of 10 to 45 mg. by various routes, including intravenous injection, intratracheal instillation, and cage dusting. From the results of the experiments it was concluded that the pure silicates did not induce collagen lesions even when present in large quantities, although they did possess various levels of proliferative activity. Silica itself, even in quantities of 10 mg. produced nodules with a collagen fiber formation and with a tendency to progressive maturation. Kaolin, under all experimental conditions, showed an activating capacity on silicotic lesions. Montmorillonite may be considered to have similar activating qualities but the picture was unclear since the lesions were not simply pneumoconiotic but possessed a combination aspect with that of interstitial pneumonitis. The sedimentation clay from loess generally had an inhibiting activity on lesions when administered intratracheally but was inactive when administered intravenously. Feldspar inhibited silicotic lesions on intratracheal administration. By the intravenous route there was a relatively active proliferation in the presence of silica but it

was stated that in larger doses with slower elimination the activity would not be very important. Mica given intratracheally had an inhibiting activity on silica but was accompanied by the presence, nevertheless, of several nodules in the lungs, a fact that was not noted with other silicates. When administered intravenously the activity was cumulative sooner with regard to the production of the nodules as well as the extension of the fibrotic lesions. Its inhibiting activity was therefore doubtful. (LC)

4015. Effect of Quartz Powder on Tubercle Bacilli and Phagocytes. T. EBINA, Y. TAKAHASHI, and T. HASUIKE. *Amer. Rev. Respirat. Diseases* **82,** 516–27 (Oct. 1960).

It was observed in mice that quartz particles injected subcutaneously stimulated the growth locally of the BCG organisms which had subsequently been inoculated intravenously into the animals. The multiplication of BCG organisms was, however, only infrequently observed at the site where non-silicogenic particles, such as bismuth subnitrite, were injected. The intravenous administration of quartz particles had been shown to increase the susceptibility of mice to BCG when injected by the intravenous route. In experiments *in vitro*, using a cell suspension of mononuclear cells, no multiplication of BCG was observed in the mononuclear phagocytes ingesting non-silicogenic dust particles; silicogenic particles such as quartz, sericite, or kaolin, destroyed the phagocytes very markedly (See also APCA No. 3732). The results obtained from the present experiments suggest that the extensive destruction of mononuclear phagocytes may be one of the causative factors which enhance extensive multiplication of tubercle bacilli in silicotic foci or produce progressive tuberculosis in silicotuberculotic patients. (LC)

4016. [Contribution to the Action of SO_2 on the Organism.] Prispevek ke studiu pusobeni SO_2 na organismus. L. ERBAN and J. KORINEK. **Cesk. hyg.* (Prague) **5,** (2–3) 121–7 (1960).

The present paper is concerned with investigations of changes in the reactivity of the organism during the chronic action of small doses of sulfur dioxide by means of immunological methods. For this purpose it was necessary, in the first place, to solve the problem of continual dosage of sulfur dioxide by devising an air-proof chamber for the laboratory animals. The experiments were done on 20 male rabbits. Half of the number were exposed to the action of sulfur dioxide and the second half served as controls. The first group of animals inhaled a mixture of air and SO_2, the latter having an average concentration of 36 mg./m.^{3}. The exposure lasted for 9½ hours during an uninterrupted period of 80 days. As criterion of reactivity of the organism the formation of antibodies in response to the administration of a foreign protein was used. The titer of antibodies was assessed according to Ouchterlon's precipitation. In addition, immunoelectrophoresis of the serum was carried out according to Grabar's method. The experiments suggest that even low concentrations of SO_2 (36 mg./m.^{3}) reduce the antibody formation in rabbits. (Authors' English summary —LC)

4017. Tuberculosis: A Study of Its Synergistic Mechanisms. P. GROSS, M. L. WESTRICK, and J. M. MCNERNEY. *J. Occupational Med.* **2,** 571–5 (Dec. 1960).

Iron-contaminated quartz dust, when injected intratracheally (50 mg. dust in 1 ml. of saline) in combination with 0.01 ml. PPD tuberculin into sensitized guinea pigs, produced a greatly exaggerated tissue response. In many of the animals the resulting disease resembled experimental tuberculosilicosis. The modification of experimental silicosis by an immune reaction, as exemplified by the pulmonary tuberculin reaction, supports the hypothesis that the development of tuberculosilicosis is dependent upon a reciprocal stimulation of tissue responses caused respectively by silica dust, on the one hand, and by sensitivity to the tubercle bacillus and its products, on the other, as postulated by Vigliani and Pernis (APCA No. 3820). (Authors' summary—LC)

4018. A Health Hazard Associated with Epoxy Resin-Concrete Dust. R. E. JOYNER and W. L. PEGUES. *J. Occupational Med.* **3,** 211–14 (Apr. 1961).

An episode is reported in which six laborers developed upper respiratory irritations from inhaling the dust and/or vapor which emanated during the destructive removal of epoxy resin-concrete during a 5-day period in early April 1959. Epoxy resin-concrete is a general name applied to commercial mixtures of an epoxy resin and concrete aggregate, the mixture being currently available for use in grouting where high strength, imperviousness to oil, or resistance to chemicals is required. It had been generally stated that polymerized "hardened" resin had little or no physiological activity upon the skin or mucous membranes. In Great Britain, however, it had been found that tooling operations on hardened resin gave rise to decomposition products which were irritating to the skin and mucous membranes. Four of the men were using air impact hammers while the other four played streams of water over the area of each hammer contact. Secondary infection occurred in three of the patients. A mild, nephrotoxic action was thought to be observed in all six patients. The offending agent was not conclusively identified but was thought to have been xylene, amine salts, or other unknown resin decomposition product. (LC)

4019. [Electron Microscopic Investigations of the Development of Dust Granulomas.] H. J. LÖBLICH. *Beitr. Silikose-Forsch.* (Bochum) **No. 71,** 1–51 (1961).

Silicotic granulomas were produced in 20 albino rats by the injection of 50 mg. of quartz dust into a subcutaneous pocket. The granulomas were examined by means of electron microscopy 7, 14, 21, and 28 days following the injection. The dust was found intracellularly and within the cytoplasm outside the double layers of ergastroplasm. Following an initial increase of function, the phagocytes dissolve as a result of the cytotoxic effect of the dust. The dust becomes free again and undergoes new phagocytosis. This procedure goes on until the fibrous changes of the granuloma are complete. Organic substances on the surface of the quartz particle are dissolved by the protein-catabolishing ferments of the cell. Electron microscopy shows that the cytotoxic and fibrocytic effect of quartz is greater than when compared with the effect of other silicotic modifications. The mechanisms of the effects of quartz dust are discussed with regard to the different theories concerning the pathogenesis of pneumoconiosis. (LC)

4020. [C-Reactive Proteins and Mucoproteins in Silicosis and Silicotuberculosis.] La proteina C-reattiva e le mucoproteine nella silicosi e nella silicotubercolosi. A. MONTEVERDE and E. FUMAFALLI. *Folia Med.* (Naples) **43,** 813–31 (Sept. 1960).

A study of the behavior of protein C and of the perchloro-soluble mucoproteins in a group of 90 silicotic and silicotuberculous patients, is described by the authors. In complicated, massive, and tuberculosis-associated silicotic types, the two tests appear to be positive in a parallel manner. In the purely silicotic situation, the constantly increasing mucoprotein values correspond in the majority of cases to a prevalently negative protein C value. The difference in values is believed by the authors to be related to the difference in significance assumed by either test in silicotic disease: while a positive value for protein C appears to reveal the presence of aspecific and specific inflammatory processes by which silicosis is complicated, the increased muco-proteins might tend to indicate the intrinsic evolving processes of silicotic disease. Silicosis is explained, according to Vigliano's concepts, as a pathological condition of the connective tissues and is, therefore, to be included in the wide and ill-defined group of the collagenoses. (Authors' summary, modified—LC)

4021. [On the Binding of Carbon Monoxide in the Blood in Acute and Chronic Carbon Monoxide Poisoning.] Sul legame del CO nel sangue nell'ossicarbonismo acuto e cronico. L. PECORA, C. VECCHIONE, and S. FATI. *Folia Med.* (Naples) **43,** 568–80 (June 1960).

Experimental studies *in vitro* were made by the authors of the stability of the carbon monoxide linkage with the blood subsequent to acute or chronic poisoning. In acute poisoning a group of 12 rabbits were exposed on the 1st, 5th, 10th, and 20th days; in chronic poisoning a similar group of rabbits were exposed for 120 days with the carbon monoxide at a level of 100 ppm. For each type of poisoning the CO levels were determined for newly-drawn samples of blood and of samples which had been exposed to the air for varying periods. From results of these studies it was shown that the greater the number of acute poisonings, or the more prolonged the chronic poisoning, the less was the quantity of CO freed from the red cells or from the plasma after exposure to air. There was, therefore, a progressive increase in both the plasma and globulin carboxyemia. From these studies it is evident that in repeated poisonings CO is not only distributed in the blood in a different way compared with single poisonings, but also that links which are unlikely to be reversible are established both in the plasma and in the red blood cells. (Authors' summary—LC)

4022. The Effects of Dusts on Peritoneal Cells within Diffusion Chambers. E. V. ROWSELL, G. NAGELSCHMIDT, and R. C. CURRAN. *J. Pathol. Bacteriol.* (London) **80,** 337–44 (Oct. 1960).

Diffusion chambers containing silica dust and peritoneal cells were inserted intraperitoneally in rats. Control chambers

were empty or contained cells only or cells combined with diamond or feldspar dust. In all chambers most of the cells soon died but fibroblasts grew. In the presence of dust these proliferated to a greater extent and formed more hyaline collagen. Silica was no more effective in producing these effects than feldspar or diamond. No substance irritant to the tissues was liberated from any of the chambers. (LC)

4023. Current Concepts of Pneumoconioses—Clinical Aspects. O. A. SANDER. *J. Amer. Med. Assoc.* **172,** 1587–90 (Apr. 9, 1960).

Because of diversified, present-day opinions on the clinical aspects of the pneumoconioses, the author feels that it is imperative to know who is using the term "pneumoconiosis." He defines pneumoconiosis as it is used by: (1) the pathologist, who speaks of it as "retained particulate material in focal areas in the lungs, or fibrous tissue reaction to a fibrogenic dust"; (2) the radiologist, who employs pneumoconiosis as "a pattern of generalized nodular shadows, with or without associated conglomerate shadows"; and (3) other physicians, especially the chest specialist, who utilize the term in a combination of both previous concepts, combined with a detailed understanding of which dust may or may not be harmful, the conditions of dustiness, and the association of the dust with other factors which may change the primary pattern. The author also illustrates the consequences of basing a diagnosis of silicosis on roentgenograph findings alone by using a case history of a man who filed a claim for compensation after a chest x-ray revealed diffused, irregular nodulation in the lung shadow. Reexamination after 10 months of employment and worry showed that the abnormality was no longer present and, because of the initial mistaken diagnosis, the real cause was never determined. In order to prevent unfortunate diagnoses, he suggests that the well-known triad of diagnostic criteria, which includes (1) the medical history, (2) the roentgenographic patterns, and (3) the results of physical, physiological, and laboratory examinations, be scrupulously applied. (LC)

BIBLIOGRAPHIES

4024. A Current Bibliography on Allergy and Applied Immunology. Series IV. J. FORMAN. **Rev. Allergy Appl. Immunol.* **14,** 669–714 (1960).

In this bibliography under the section on Allergy, the subject headings are: Experimental Anaphylaxis and Allergy; Clinical Types (allergic dermatoses, collagen disease, drug reactions); Respiratory (asthma); Pulmonary Disorders; Fungus Infections; Air Pollution (pages 691–692); Histamine and Antihistaminic Agents; and Tissue Transplantation. Under Applied Immunology, are: General and Experimental; Phage; Cancer; Blood and Blood Groups; Immunodiagnosis; Vaccination; and Viruses. This extensive bibliography of over 1000 references appears to be compiled from the literature published in 1959 and 1960. (LC)

4025. [Dust Technology.] Staubtechnik. W. GRÜNDER. *VDI Zeitschrift* (Düsseldorf) **103,** 683–6 (May 1961).

This annual survey of the various aspects of dust technology is accompanied by a bibliography of 55 references all but a few items of which were published in 1959 and 1960. The information is reviewed and discussed briefly under the headings of: dust counting techniques; dust hygiene; combustible industrial dusts; dust technology; and dust emission and dust depositing. (LC)

NEW JOURNALS ADDED IN THIS ISSUE

Brit. J. Diseases Chest
British Journal of Diseases of the Chest
Baillierre, Tindall and Cox
7 & 8 Henrietta St.,
London WC 2, Eng.

Cesk. hyg.
Ceskoslovenská hygiena
Statní zdravotnické nakladatelství,
Prague, Czech.

Geograficky Casopis
Vydavatel'stvo Slovenskej Akadémie Vied
Kelmensova 27,
Bratislava,
Czech. C.S.S.R.

J. Biochem. Microbiol. Technol. Eng.
Journal of Biochemical and Microbiological Technology and Engineering
Interscience Publ., Ltd.,
88–90 Chancery Lane,
London WC 2, Eng.

J. Hist. Med.
Journal of the History of Medicine and Allied Sciences
Department of the History of Medicine
Yale University,
New Haven, Conn.

J. Sci. Labour
The Journal of Science Labour
The Institute for Science of Labour
Soshigaya II, Setagaya-ku,
Tokyo, Japan

Kokuritsu Kōshu Eiseiin; Bull. Inst. Public Health
Kokuritsu Kōshu Eiseiin; Bulletin of the Institute of Public Health
The Institute of Public Health,
Tokyo, Japan

Príroda a spoločnosť
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Stalingradska 8,
Bratislava. C.S.S.R.

Rev. Allergy Appl. Immunol.
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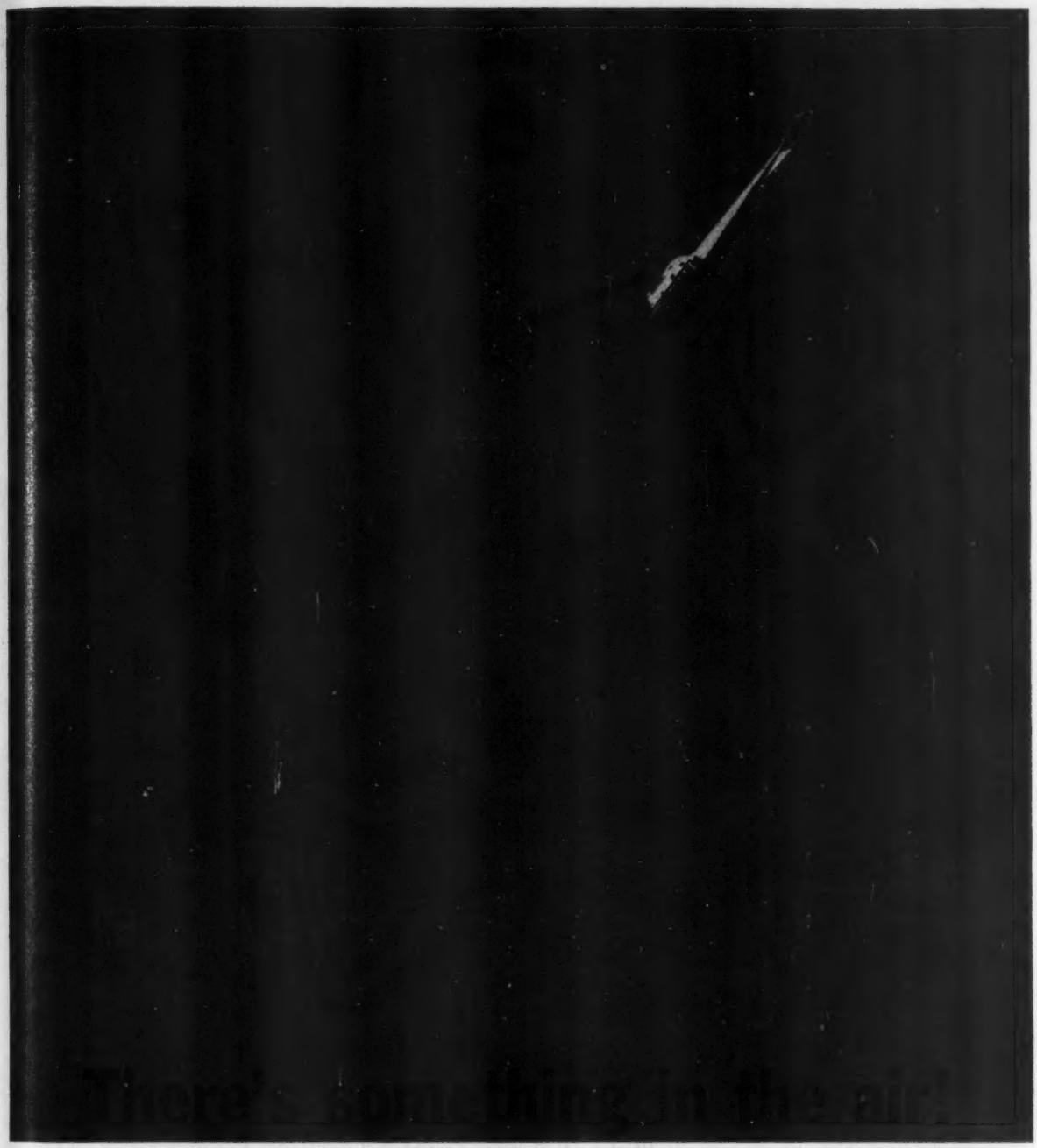

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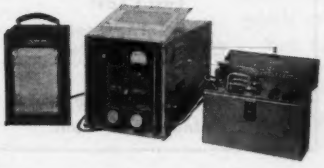

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Secretary's Page

Local Sections

One of the most vital areas for APCA's membership and Board of Directors which requires attention is that of the relationship of the local sections to the national organization. At present there are eight sectional groups: Niagara Frontier Section, Southwest Section, Mid-Atlantic Section, West Coast Section, East Central Section, New England Section, Ontario Section, and MAPPA. The story appearing about the East Central Section's highly successful meeting in Louisville, Kentucky, indicates that after 18 years, the East Central Section is stronger than ever and furnishes an excellent meeting place for APCA members not only in that area but from the rest of the country at times other than the Annual Meeting.

APCA's Board of Directors has had a statement of policy on sectional organization since May 23, 1955. In view of renewed interest recently in the formation of several new sections the statement of policy will be quoted for the information of the members in the December issue of the JOURNAL.

At its Board meeting this year in New York on June 12, APCA's Board of Directors initiated two new By-Law amendments which will be acted upon by the By-Law committee. If the membership approved these By-Laws they will be incorporated and then will furnish the mechanism for the formation of many new local sections. It has long been felt that local sections are the grass roots of any large association, and they furnish the impetus for sustained membership drives. An Ad Hoc committee of relations of local sections to national organization was begun under the chairmanship of Louis E. Bunts last year. This Ad Hoc committee will be continued again this year as has already been announced by our President Dr. W. L. Faith. By means of this announcement, the Board of Directors invites all members of APCA to indicate their desires on the many problems of these relationships by writing headquarters. Some of the problems which have already been discussed are dues structures, proceedings, suitability of papers for JOURNAL publication, geographical areas, international sections, membership solicitation programs, and value of "meetings in miniature." Your Board of Directors earnestly solicits any ideas on this most important problem.

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The price of additional copies is as follows: For members of the West Coast Section, $1.00*; For members of APCA, not members of the West Coast Section, $1.50*; For nonmembers of APCA or of the West Coast Section, $2.00.*

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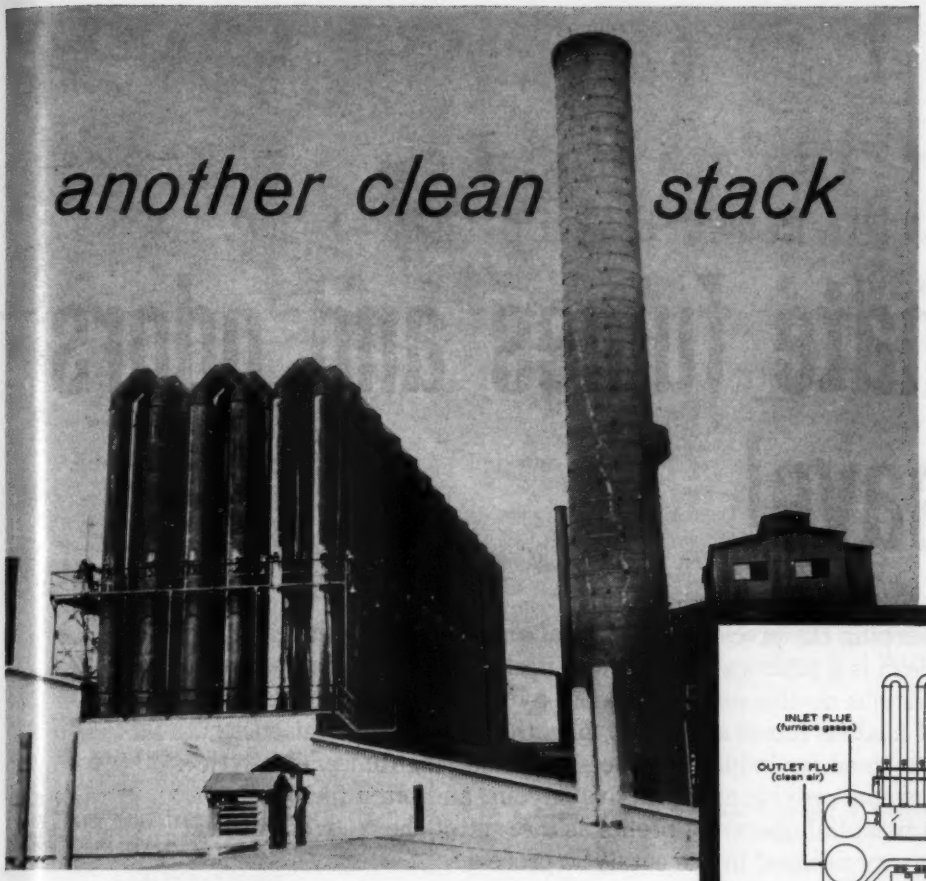
In Memoriam

It is with deepest regret that we announce the death of Dr. George H. Young, who served as Fellowship Advisor to APCA at Mellon Institute. He died October 10, 1961.



(Left) Cooling tubes atop Glass-Bag Filter housing lower furnace gas temperature from 800°F. to 450°, a full 150° below maximum advisable operating temperature. Clean stack proves that filter removes all visible dust.

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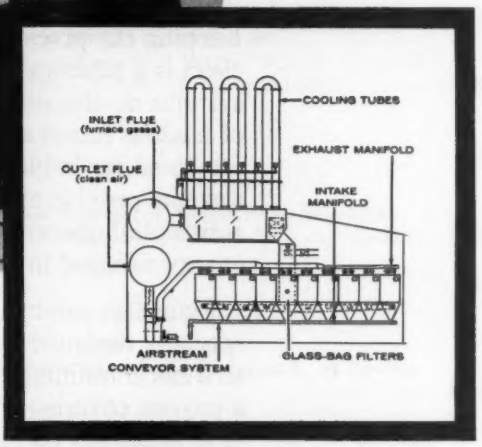

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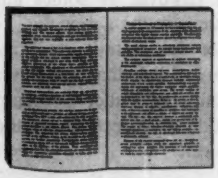

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FOUNDED 1907

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The Editor welcomes writers interested in air pollution problems and encourages them to use the pages of this journal for the expression of their opinions. But neither he nor the Association assumes responsibility for the validity of the opinions expressed herein.

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EVALUATION *of* AIR CLEANERS *for* OCCUPIED SPACES*,†

KENNETH T. WHITBY, Assistant Professor, **DALE A. LUNDGREN,** Research Assistant, **ANDREW R. MCFARLAND,** Research Assistant, and **RICHARD C. JORDAN,** Professor and Head, Mechanical Engineering Department, University of Minnesota, Minneapolis, Minnesota

Air cleaners may be classified as industrial gas cleaners or occupied space air cleaners. In general, industrial gas cleaners are designed to operate at high dust loadings, cleaning the effluent air before discharge into the atmosphere. Air cleaners for occupied spaces, however, are designed to operate at low inlet concentrations, cleaning the air of particulate matter and other contaminants so that the effluent can be discharged into occupied areas.

Because there is widespread application of air cleaners in ventilation, heating, and air conditioning systems, a large number of cleaners of varied performances are available. To evaluate the performance of these cleaners, numerous testing and rating methods have been used or proposed.[1–6] Since various aerosols and methods of evaluation are used, the results from the different tests are often difficult to compare.

Considerable performance data are available both from manufacturers and from the literature. The Harvard Air Cleaning Laboratory has published numerous reports and papers describing their testing of gas cleaners. Also the National Bureau of Standards has long evaluated air cleaners for the government. NBS test methods[2] and results of their work are well known. The Navy,[7] as well as other branches of the armed forces, has conducted extensive investigations using methods designed to reveal the suitability of air cleaners for specific applications. The literature also contains numerous reports of scientific investigations in which the properties of air cleaners were studied.[8–12]

The principal objective of this study was to gather data by a variety of test methods on enough air cleaners so that a general picture of their performance could be obtained. Although all of the air cleaners were not tested by every method, sufficient data have been obtained to realize this objective.

The primary considerations in selecting air cleaners for this study were whether they were representative of a class or type of commercial importance, and whether they could be tested with the available facilities. In addition to those air cleaners chosen for this study, data on previously tested air cleaners are included where applicable. A complete listing and description of the air cleaners are given in Table I.

Experimental Methods

Necessary apparatus includes aerosol generators or dust feeders, test duct, sampling system, and sample evaluation equipment. The general design of the apparatus used here has been described previously.[6, 14] New apparatus not previously described includes a 20-inch square test duct and several aerosol generators.

Air cleaner efficiency tests, made by integral sampling combined with photometric, microscopic, and weight measuring techniques, were run on the

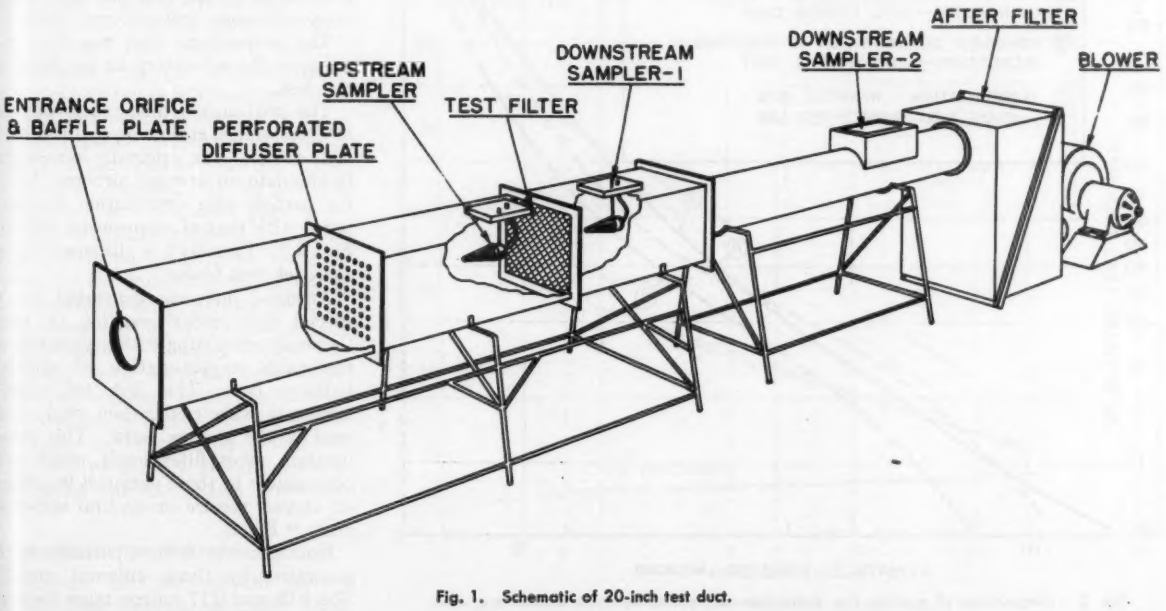


Fig. 1. Schematic of 20-inch test duct.

* Presented at the 54th Annual Meeting of APCA, Commodore Hotel, June 11–15, 1961, New York, New York.

† This paper is the result of research sponsored by the U. S. Public Health Service, Grant No. S-23(C-5) in co-operation with the Mechanical Engineering Department, University of Minnesota.

Table I—Parameters and Description of Air Cleaners

Filter Code Number	Filter Name	Filter Size	Adhesive	Fiber Shape	Fiber Density, ρ_f, gm/cm³	Weight/Unit Area, w, gm/cm²	Media Thickness, L, cm.
1	Glass mat "A"[a]	12 x 12 in. pleated	None	○	2.34	0.0107	0.8
2	Glass mat "B"[a]	12 x 12 in. pleated	None	○	2.34	0.00459	1.0
3	Glass mat "C"[a]	12 x 12 in. pleated	None	○	2.34	0.00492	0.7
4	Glass mat "D"	3½ in. disc in holder	None	○	2.34	0.01165	1.7
5	Fiber mat "A"	3½ in. disc in holder	None	8	1.5	0.0139	0.32
6	Fiber mat "B"	3½ in. disc in holder	None	8	1.5	0.0246	0.93
7	Fiber mat "C"	3½ in. disc in holder	None	8	1.5	0.00412	0.05
8	5 ply paper	3½ in. disc in holder	None	8	1.5	0.00996	0.15
9	10 ply paper	3½ in. disc in holder	None	8	1.5	0.0192	0.3
10	IPC paper[a]	3½ in. disc in holder	None	8	1.5	0.0144	0.1
11	Cloth mat[a]	20 x 20 in. pleated	None	8	1.5	0.00736	0.2
12	Whatman 41[a]	3½ in. disc in holder	None	8	1.5	0.00928	0.03
13	Dacron bag filter media	3½ in. disc in holder	None	○	1.5	0.0368	0.077
14	20 oz felt[a]	3½ in. disc in holder	None	○	1.5	0.0318	0.35
15	MSA 1106 BH	3½ in. disc in holder	None	○	2.34	0.00571	0.035
16	Refractory media	3½ in. disc in holder	None	○	2.34	0.059	0.35
17	Wire filter "A"	12 x 12 x 2 in.	SAE No. 30 oil	○	7.85	1.37	5.0
18	Wire filter "B"	12 x 12 x 2 in.	SAE No. 30 oil	○	7.85	1.95	5.0
19	Permanent aluminum "A"[a]	20 x 20 x 2 in.	Mfg. adhesive	\	2.70	0.162	7.0
20	Permanent aluminum "B"[a]	12 x 12 x 2 in.	Mfg. adhesive	\	2.70	0.487	4.0
21	Polyethylene[a]	20 x 20 x 1 in.	None	○	1.05	0.0558	0.4
22	Coarse foam[a]	20 x 20 x 1 in.	None	△	1.05	0.0741	2.54
23	Fine foam[a]	20 x 20 x ½ in.	None	△	1.05	0.0492	1.45
24	1 in. throwaway[a]	12 x 12 x 1 in.	Mfg. adhesive	○	2.34	0.0239	2.54
25	2 in. throwaway	12 x 12 x 2 in.	Mfg. adhesive	○			
26	AFI calibration[a]	12 x 12 x 2 in.	SAE No. 30 oil	□○	8.1	0.273	5.0
27	Electrified media (on)[a]		None	○	2.34	0.00711	0.1
28	Electrified media (off)[a]		None	○	2.34	0.00711	0.1
29	Electrostatic[a]	22 x 24 in.	Mfg. adhesive				
30	10 μ special glass	3½ in. disc in holder	None	○	2.34	0.0235	0.33

[a] Selected specifically for this study.

selected air cleaners using a variety of test aerosols.

Test Duct and Sampling System

A schematic of 20-inch test duct is shown in Fig. 1. It consists of an entrance orifice and baffle which provides turbulent mixing of the entering aerosol and air. The large scale turbulence is broken up by the perforated diffuser plate resulting in a uniform dust distribution and a flat velocity profile at the test section. The air leaving the test section is metered, filtered to remove most of the residual aerosol, and exhausted outside the laboratory. Maximum air capacity is about 1500 cfm.

The sampling system[6] consists of two heads accommodating 47 mm diam sampling filters, rate and volumetric air flow meters, control valves and a vacuum pump capable of drawing seven cfm free air at 15 in. Hg. The system is designed to provide isokinetic sampling over a broad range of air cleaner efficiencies and duct velocities.

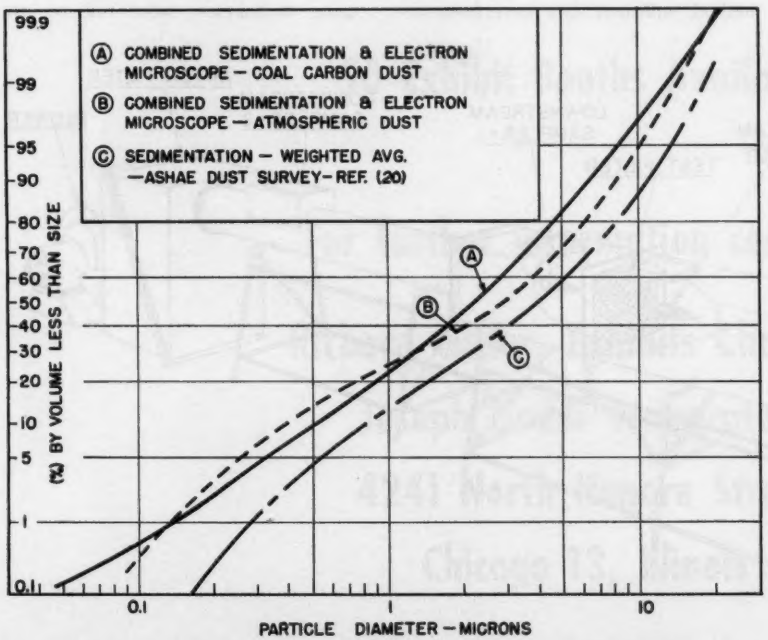


Fig. 2. Comparisons of particle size distribution of coal-carbon with atmospheric dust.

Aerosols and Aerosol Generators

The six different aerosols used in this study were natural atmospheric dust, coal-carbon, coal-carbon and lint, homogeneous methylene blue particles, short ragweed pollen, and airborne bacteria.

The atmospheric dust was that existing in the laboratory at the time of the test.

The coal-carbon dust, consisting of 80% ball-milled anthracite coal and 20% K-1 carbon, was originally developed to simulate an average airborne dust.[8] Its particle size distribution is compared with that of atmospheric dust in Fig. 2.[20] This dust is dispersed by a sonic jet dust feeder.[6]

Artificial lint was generated by a special lint feeder[6] capable of continuously converting cotton yarn into a reasonable approximation of natural airborne lint. This lint, fed simultaneously with coal-carbon dust, was used in the loading tests. This combination gives filter loads which are comparable to those obtained in actual air cleaner service on natural airborne dusts,[19] Fig. 3.

Homogeneous aerosol particles were generated by three different means. The 0.08 and 0.17 micron mass median

Table I—Parameters and Description of Air Cleaners

Fiber Volume Fraction α	Effective Fiber Diameter, microns	S_{fe}	$S_{fe}D_{fe}^{-1/2}$ — $cm^{-1/2}$	Media Area, ft^2	Nominal Area, ft^2	Media Velocity, fpm	Clean Pressure Drop, Δp-In. W. G. H_2O	Stain Efficiency on Coal Dust, %	Weight Efficiency on Coal Dust, %	Stain Efficiency on Atmospheric Dust, %	Weight Efficiency on Atmospheric Dust, %
0.0057	4.16	14.0	687	4.9	1.0	25.4	0.10	34.3	67.4	20.9	
0.0020	1.69	15.0	1155	4.9	1.0	25.4	0.18	80.7	97.0	61.1	
0.0030	1.06	25.2	2450	4.9	1.0	25.4	0.34	92.3	98.9	70.8	
0.0030	1.18	54.0	4580	0.049	0.049	42	1.4	98.2			
0.0292	6.91	17.1	650	0.049	0.049	42	0.2	27.2	70.8		
0.0177	48.0	4.40	63.6	0.049	0.049	42	0.03	14.5	45.8		
0.055	17.6	1.99	47.5	0.049	0.049	42	0.013	9.6	40.2		
0.045	14.5	5.85	154	0.049	0.049	42	0.07	17.1	50.2		
0.043	12.2	13.4	384	0.049	0.049	42	0.13	20.7	63.3		
0.096	10.1	12.1	381	0.049	0.049	42	0.13			9.0	
0.025	10.6	5.89	181	19.5	2.57	57	0.12	11.2	45.4	2.9	33.7
0.206	3.69	21.4	1110	0.049	0.049	42	1.23	86.3		88.0	
0.319	8.85	35.2	1180	0.049	0.049	42	1.57	40.7	89.9		
0.061	11.7	23.0	673	0.049	0.049	42	0.135	33.5	68.1	20.2	48.9
0.07	0.4	77.8	12,300	0.049	0.049	25	3.5	99.95			
0.065	2.52	127	5040	0.049	0.049	10	0.98	99.92			
0.035	1020	2.2	6.9	1.0	1.0	520	0.13	6.1	29.9		
0.05	815	3.94	13.8	1.0	1.0	500	0.17		39.6		
0.0086	166	4.58	35.5	2.31	2.31	600	0.2	0.1	25.2	0	21.3
0.045	4780	0.48	0.69	1.0	1.0	520	0.12	5.7	15.8		
0.133	258	2.62	16.3	2.39	2.39	350	0.165	3.7	47.6	4.5	8.2
0.028	211	4.2	29	2.38	2.38	350	0.103	1.0	22.6	0.8	10.4
0.0322	36.7	16.2	268	2.38	2.38	120	0.175	10.8	48.3	10.5	40.4
0.004	42.2	3.10	47.8	1.0	1.0	300	0.085	8.4	50.7	8.7	27.7
				1.0	1.0	300	0.087	6.9	52.0		
0.0067	105	4.1	39.0	1.0	1.0	300	0.05		44.0		
0.0304	35.2	1.1	18.5	107	3.04	9.8	0.038	62.9	67.8	25.7	39.6
0.0304	35.2	1.1	18.5	107	3.04	9.8	0.038	9.1	30.5	5.6	13.7
					3.8	650/500	0.38	92.5		90.5	
0.0304	8.82	14.5	488	0.049	0.049	42	0.135				

[a] Selected specifically for this study.

diameter (σ_g = 1.3) methylene blue aerosols were generated with a Collison atomizer[16] in combination with a special impactor.[15]

Homogeneous methylene blue particles between 0.5 and 14 microns were produced with a spinning disk generator.[15] These aerosols had a σ_g of 1.05.

Both the atomizer-impactor and spinning disk generators produce electrically neutral aerosols by mixing the evaporating droplets with a high concentration of positive and negative ions generated by a sonic jet ionizer.[17] Neutralization of the aerosol charge was necessary for satisfactory operation and application of the generators.

Short ragweed pollen was used as a 20-micron homogeneous aerosol. The pollen was dispersed by an air jet through a simple S-shaped glass tube.

It was originally intended to use the normal airborne bacteria as the test aerosol for the bacteria tests. Because the concentration of natural airborne bacteria was too low, an artificial aerosol was created by shaking cloths impregnated with Serratia marcescens. While this technique raised the bacteria concentration to measurable levels, the variability in the efficiency determinations was so great that only general conclusions can be drawn from the data.

Sample Evaluation Methods

Upstream and downstream aerosol samples were collected on either MSA 1106 BH glass paper or membrane filters for all aerosols except the bacteria. Bacteria were sampled directly onto rotating culture media by means of Cassela slit samplers and evaluated by incubation and counting. The other aerosols were evaluated by photometric, count or weight measurement.

Photometric measurement was used for the evaluation of stain efficiency on atmospheric dust, coal-carbon dust and methylene blue particles smaller than four microns. The methylene blue stain was developed by carefully wetting the glass fiber paper to dissolve and adsorb the particles on the filter surface. The samples were dried at 130°F for 30 minutes before photometric readings were taken. Effects of the nonlinear relationship between the optical density and amounts on the filters were minimized by taking all samples at air flow ratios such that the upstream and downstream optical densities were with-

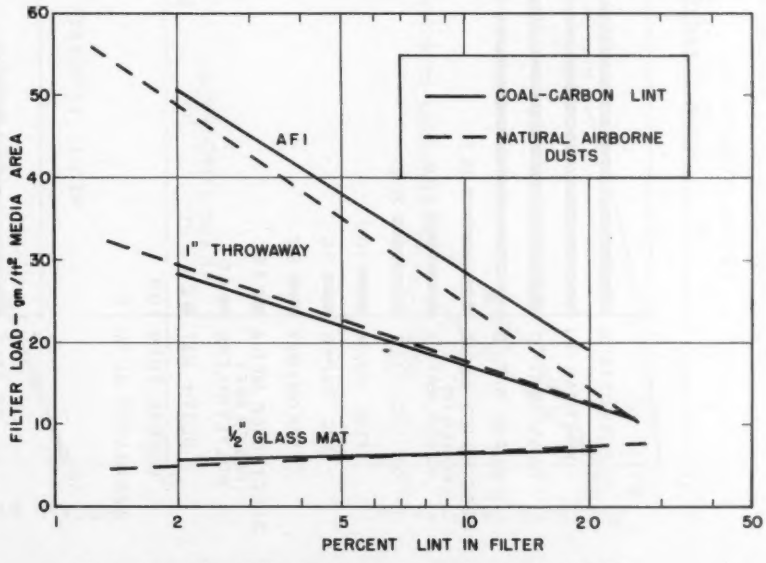


Fig. 3. Comparison of filter loading on natural and coal-carbon lint dusts.

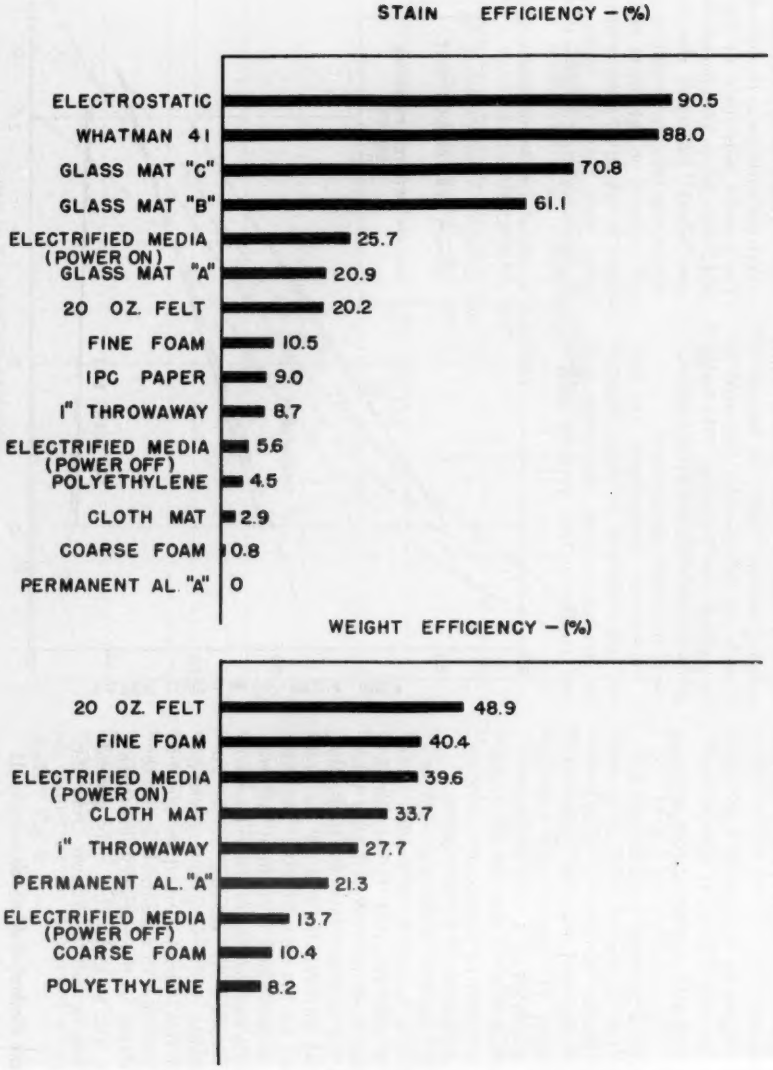


Fig. 4. Clean stain and weight efficiencies of air cleaners on atmospheric dust.

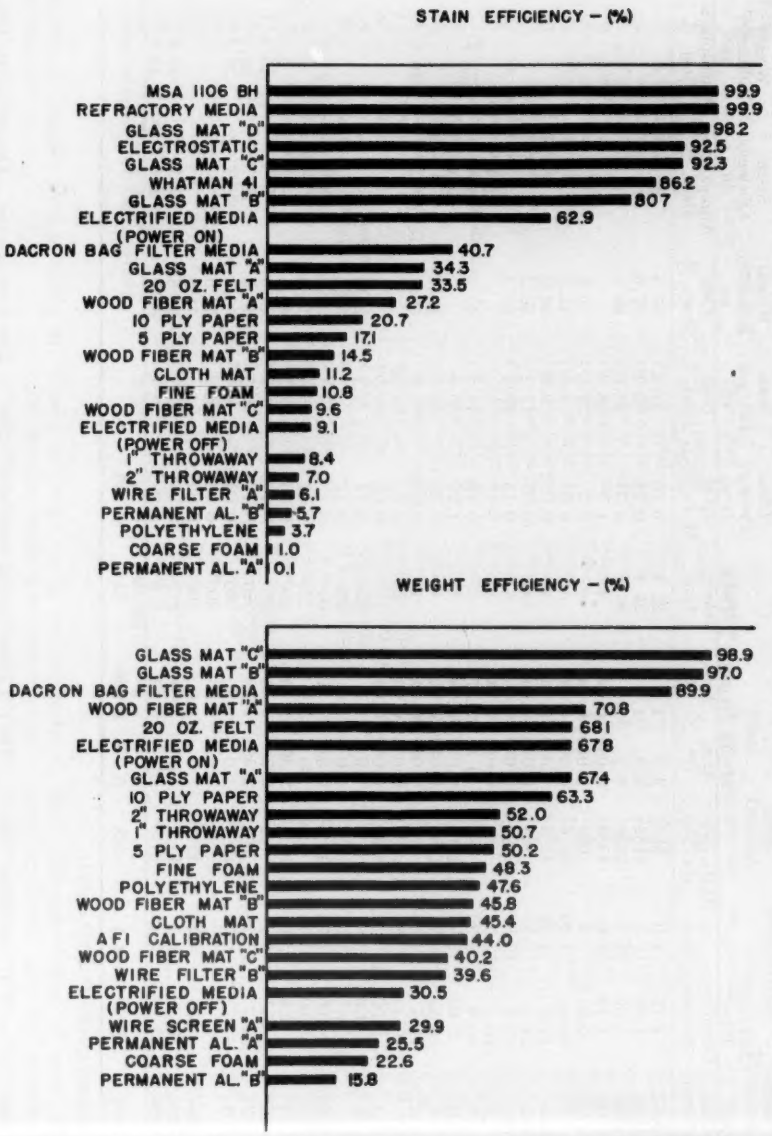
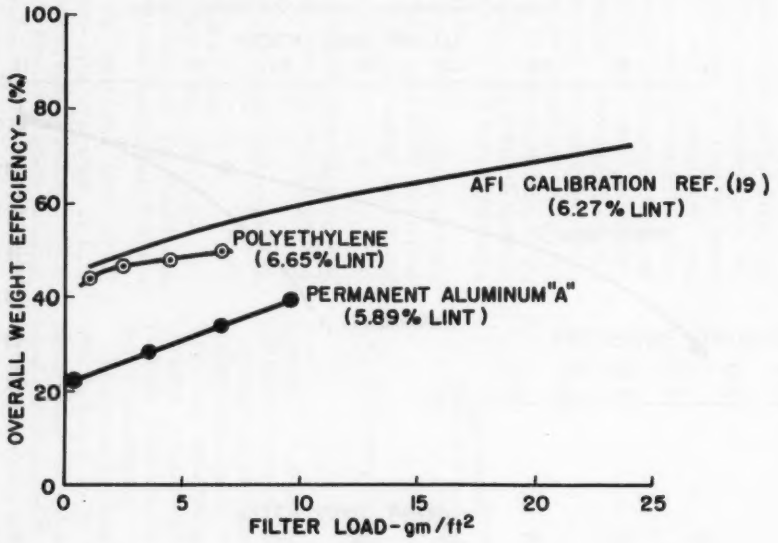
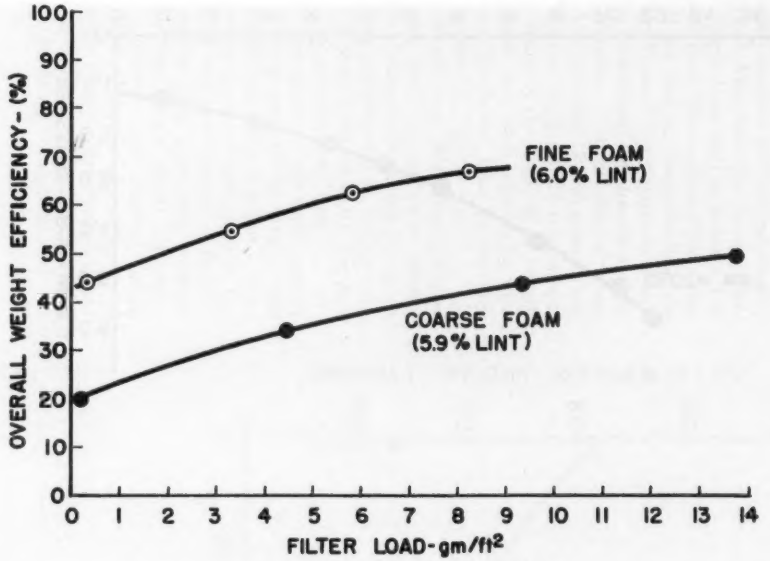


Fig. 5. Clean stain and weight efficiencies of air cleaners on coal-carbon dust (without lint).

Fig. 4. Clean stain and weight efficiencies of air cleaners on atmospheric dust.

Fig. 5. Clean stain and weight efficiencies of air cleaners on coal-carbon dust (without lint).





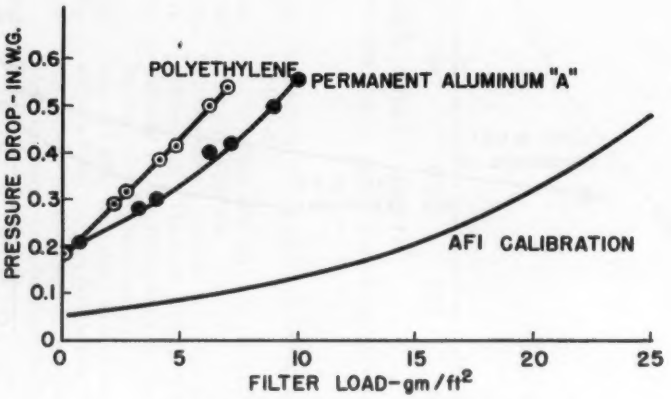


Fig. 6. Loading characteristics of three roughing filters.

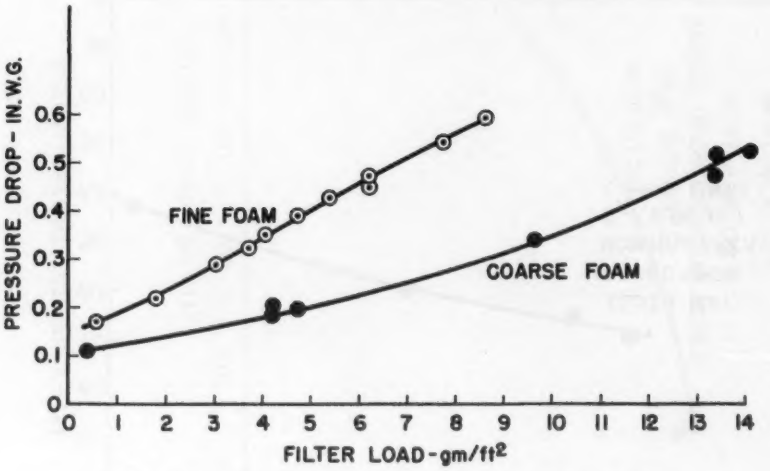


Fig. 7. Loading characteristics of coarse and fine urethane foam air filters.

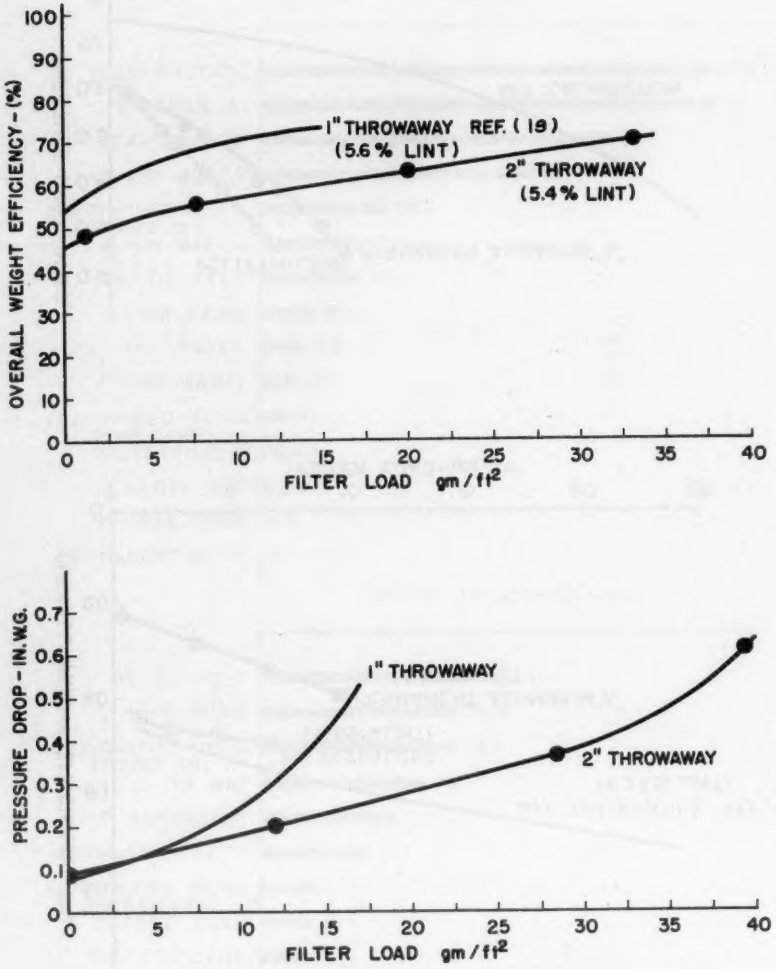


Fig. 8. Loading characteristics of throw-away air filters.

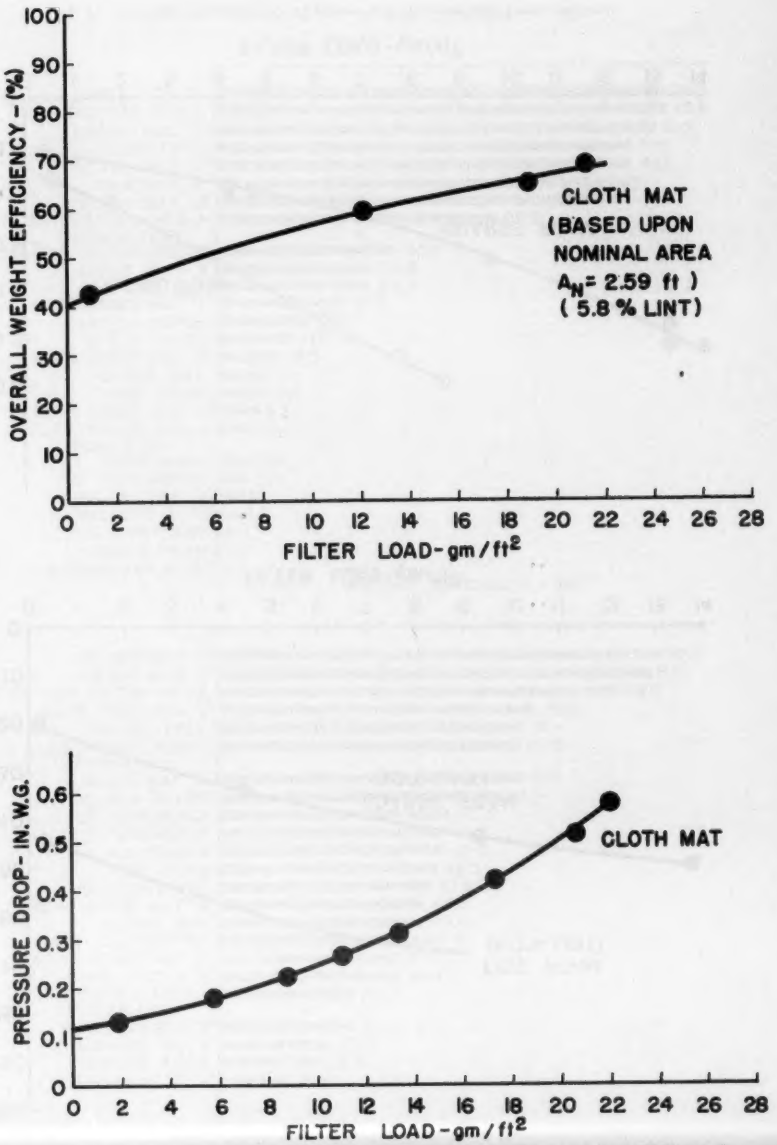


Fig. 9. Loading characteristics of a medium performance pleated filter based on nominal area.

in five percent of each other.

Particle count was used to evaluate the pollen samples and to evaluate the methylene blue samples having particles larger than four microns. For the methylene blue particles the count method was necessary because the number of particles at this size was too small to give satisfactory photometric stain measurements. The smaller of these methylene blue sizes (five to six microns) were counted using a light microscope. Visual count of the larger sizes (six to 14 microns) was made possible by wetting the membrane filter to increase particle visibility.

Weight efficiency determinations were made by sampling sufficient aerosol to collect between three and 25 mg on glass fiber sampling filters, which were weighted to an accuracy of 0.1 mg on a semi-micro analytical balance.

The particle size efficiency curves were obtained using the methylene blue aerosol and the 20-micron pollen. Considerable progress is being made in the generation and measurement of fluorescent aerosols using mixtures of methylene blue and uranine dyes. Measurement sensitivity and accuracy using fluorescent aerosols is several orders of magnitude better than that obtained with the original methods and should permit efficiency measurements to 99.99%.

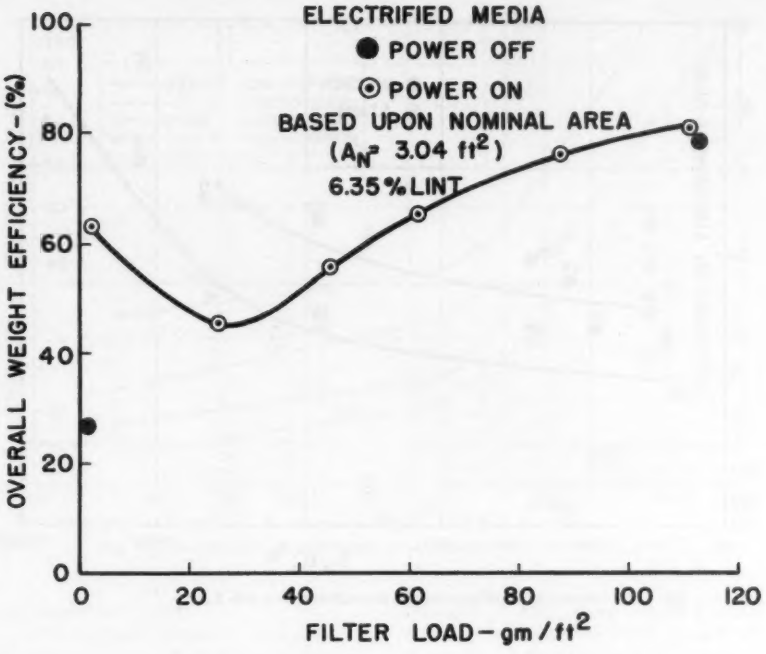
Test Procedures

Systematic techniques for testing and checking the entire system were followed throughout all tests to insure accuracy and reproducibility. One hundred percent penetration measurements (sampling without an air cleaner in the duct) were made periodically. In sampling, the velocity of air entering the sampler tips was maintained within ±20% of free stream duct velocity for all tests. Previous work has shown that a deviation from isokinetic sampling of as much as ±50% introduced only a small sampling error.

Significant loading of the air cleaners was prevented prior to the coal-carbon and lint tests by running tests in the following order:

1. Fractional efficiency determinations using methylene blue aerosol and pollen
2. Atmospheric stain and weight efficiency
3. Bacteria efficiency
4. Coal-carbon stain efficiencies
5. Coal-carbon and lint weight efficiencies and loading characteristics.

With the methylene blue aerosol usually two runs were made at each particle size on each air cleaner. Additional tests were made where the range of results was excessive. Two or more efficiency determinations were made on each air cleaner with each of the other



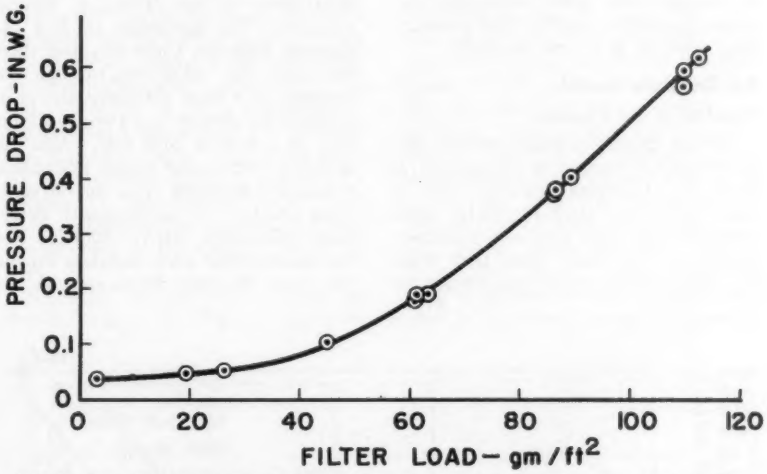


Fig. 10. Loading characteristics of the electrified media air cleaner based on nominal area.

aerosols. A total of approximately 350 test runs were made.

Atmospheric dust stain efficiency determinations required from three to 12 hours and atmospheric dust weight efficiency measurements from 24 to 72 hours depending on the laboratory dust concentrations.

The bacteria efficiency tests were run with the help of Dr. V. W. Green of the Bacteriology Department who prepared and evaluated the samples.

Coal-carbon stain tests were made by feeding the dust at 0.1 gm/min and sampling for five to 10 minutes or until an optical density of about 0.3 had been obtained.

The weight efficiency and the loading characteristics were measured using a mixture of six percent lint with coal-carbon dust. The total amount of lint and dust fed was determined by weighing the yarn reel and dust cylinder before and after each run. Points on the efficiency and pressure drop versus load curves were obtained as follows: Sampling was begun and continued until the sampler air flow could no longer be maintained (about 20 mg of dust on the sample filter). The sampling filters

Fig. 9. Loading characteristics of a medium performance pleated filter based on nominal area.

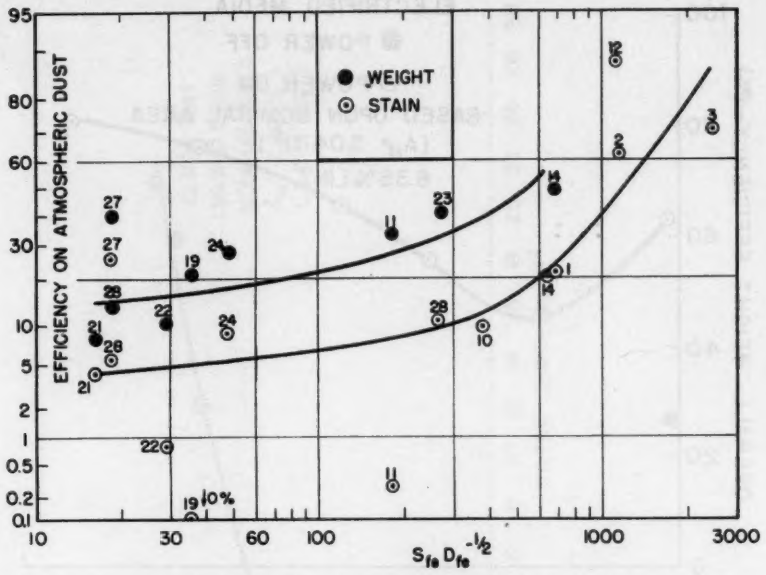


Fig. 11. Correlation of efficiencies on atmospheric dust with $S_{fe} D_{fe}^{-1/3}$.

were removed for measurement and the loading continued until the test air cleaner pressure drop rose about 1/4 of the difference between the clean pressure drop and 0.6 in W.G. Several sets of samples were taken, repeating the above procedure, until a final pressure drop of 0.6 in W.G. was reached.

Air Cleaners Tested

Selection of Air Cleaners

The air cleaners actually selected for this study are marked by an asterisk in Table I. Additional cleaners, previously tested, for which applicable data were available have also been included. Because of the many tests that were run, the number of air cleaners had to be limited. Commercial cleaners or filter media were therefore selected which were believed to be representative of the performance range and type.

Some limitations were imposed by the capabilities of the available testing facilities. The maximum air flow attainable with the University test duct was 1500 cfm. However, through the courtesy of a local company the electrostatic air cleaner was tested in their duct at a flow of 2400 cfm. Also the sampling system and sample evaluation techniques available were not of sufficient accuracy to satisfactorily determine efficiencies above 99.9%. For this reason little work was done on the very high efficiency filters such as the absolute type filters and bag filters.

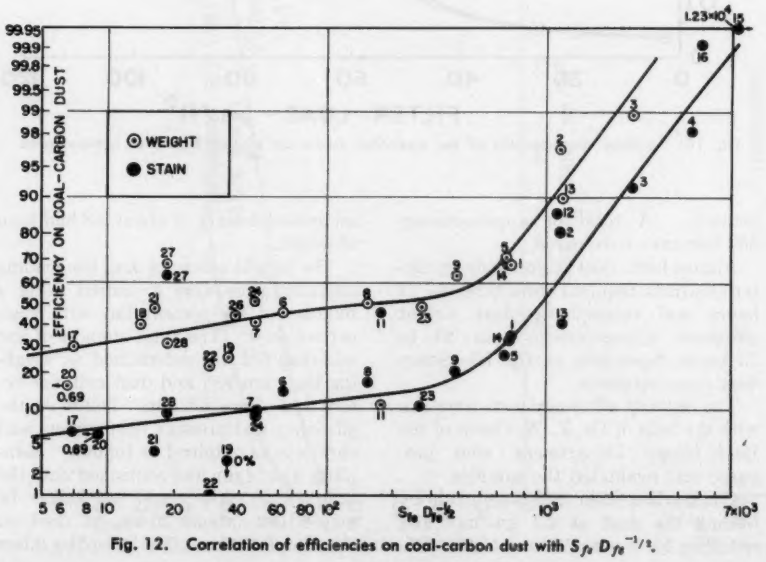


Fig. 12. Correlation of efficiencies on coal-carbon dust with $S_{fe} D_{fe}^{-1/3}$.

Description of Air Cleaners

Table I contains most of the data essential to the description of the air cleaners. Columns 1, 2, 3, and 4 give a general description of the air cleaner, the size of the unit or media tested, the adhesive, and the fiber cross-sectional shape. Columns 5 through 11 tabulate the various parameters essential to technical description of the filter mats. The true fiber density, ρ_f, was either measured or determined by reference to handbooks or previous measurements on similar materials. The weight per unit area, w, was determined by weighing a small piece of media, and the filter thickness, L, by direct measurement. The fiber volume fraction, α, was calculated by equation (1).

$$\alpha = \frac{w}{\rho_f L} \tag{1}$$

The effective fiber size, D_{fe}, was measured by an air flow technique described elsewhere.[13] The calculation of D_{fe} is based on the coefficient of drag of round fibers in an ideal filter.

The effective solidarity factor, S_{fe}, tabulated in column 10, has been calculated using equation (2) and is based on the effective fiber size, D_{fe}.

$$S_{fe} = \frac{4}{\pi} \frac{w}{\rho_f D_{fe}} \tag{2}$$

This factor is related to the over-all efficiency by equation (3).

$$\eta = 1 - \exp[-S_{fe}\eta_e] \tag{3}$$

where η_e = single fiber efficiency. Fundamentally, S_{fe} is a measure of the number of projected areas to which a particle is subjected in passing through a filter mat.

As will be shown later, the parameter $S_{fe}D_{fe}^{-1/3}$ tabulated in column 11, can be correlated with the efficiency of a clean filter on a given aerosol.

Columns 12 and 13 give the total media area and a filter nominal area, respectively. The nominal area is the projected area that a filter or filter unit presents to the airstream.

Columns 14 and 15 give the media velocity and clean pressure drop at which the tests were run. Although Table I is intended primarily to provide data descriptive of the air cleaners, the clean efficiency data in columns 15 through 19 have been provided to specify the performance range.

Comments on Particular Air Cleaners Tested

With the exception of air cleaners Nos. 5, 6, 7, 26, and 30 in Table I, the rest were commercial units.

Air cleaners Nos. 1, 2, and 3 were cartridge type pleated glass filter units having a rated capacity of 125 cfm.

Air cleaners Nos. 5, 6, and 7 were experimental cellulose fiber mats.

The IPC paper, No. 10, was included because particle size efficiency data were available for comparison with data from this study. IPC paper[12] has been used extensively for stratospheric sampling of particles.

The 20 oz felt, No. 14, has been used extensively in the University of Minnesota Particle Technology Laboratory as a test filter[6] because of its uniformity and availability in reproducible lots.

Air cleaners 15 and 16 are two high efficiency commercial filter medias having about the same efficiency but differing considerably in thickness and fiber size.

Wire air cleaners Nos. 17 and 18 are commercial high velocity filters made of window screening. These were oiled before use.

Permanent aluminum air cleaners Nos. 19 and 20 have a rather coarse ribbon-like media of expanded aluminum. Adhesive used was a dicrestyl phosphate oil.

Polyethylene filter, No. 21, is a so-called self-charging type made up of layers of varying fiber size.

Filters Nos. 22 and 23 are made of polyurethane foam.

One- and two-inch throw-away air cleaners, Nos. 24 and 25, are typical glass fiber, adhesive coated filters.

The AFI calibration filter, No. 26, is a special unit designed for standardizing panel filter testing apparatus.

The electrified media air cleaner, Nos. 27 and 28, consists of a thin glass fiber media pleated into two-inch thick panels and arranged so that a 10 to 13 kv potential can be applied across the edges of the pleats.

Electrostatic air cleaner, No. 29, is a commercial two stage unit having a 1/4 inch plate spacing and operated with about 13 kv in the ionizer and 6.5 kv on the plate section. The cell was coated with an adhesive.

Air cleaner No. 30 is a uniform special glass experimental fiber mat.

Test Results

Atmospheric Dust

The stain and weight efficiencies on atmospheric dust are tabulated in Table I and shown in Fig. 4. Several things should be noted in interpreting these data. Comparisons of these data with similar data from other sources on the same air cleaners indicate that in general, the efficiencies obtained in this study are lower. For example, Harvard Air Cleaning Laboratory[18] obtained power off weight and stain efficiencies of 42 and 18% and power on efficiencies of 62 and 32%, respectively, with atmospheric dust on the electrified media. Comparing the data of Fig. 4 with the Harvard data shows the results of Fig. 4 are somewhat lower.

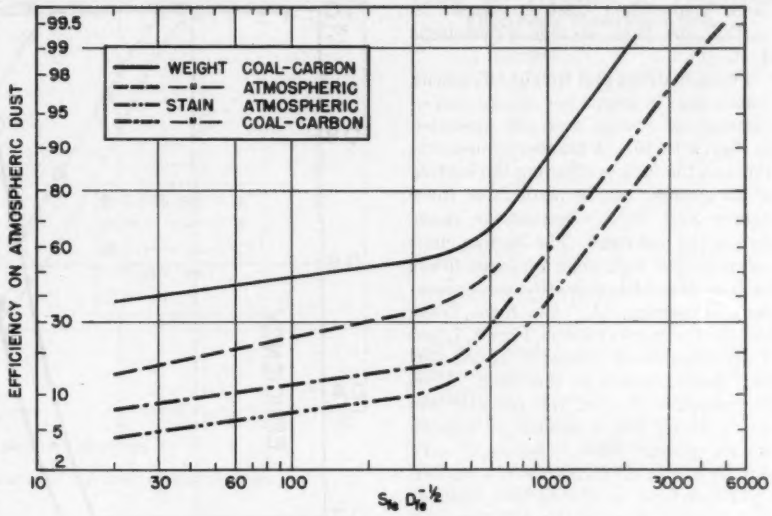


Fig. 13. Comparison of correlations on atmospheric and coal-carbon dusts.

The average standard deviation in percent of the penetration, $s/\bar{P}$, was 2.2% for the stain and 9.5% for the weight measurements. The value of $s/\bar{P}$ average for the stain determinations is much lower than would normally be expected because primarily only high penetration (low performance) air cleaners were tested, and variances in atmospheric conditions have little effect on their negligible stain efficiencies. In fact, the value of 2.2% approximates the inherent reproducibility of the duct and sampling system. These air cleaners do, however, have significant efficiencies on atmospheric weight, and the variations of atmospheric conditions are reflected in the value of 9.5% for $s/\bar{P}$.

Although the ranking of the air cleaners shown in Fig. 4 might be changed if they were retested under different atmospheric dust conditions, it is believed that the data presented are reasonable indications of the performances that can be expected.

Coal-Carbon Dust

Stain and weight efficiencies on the coal-carbon dust are shown in Fig. 5 and listed in Table I. Average standard deviation in percent of the penetration ($s/\bar{P}$) for this data is 4.4% for the stain and 5.4% for the weight measurement. Even though the coal-carbon dust is intended to simulate average atmospheric dust, comparisons of the data of Fig. 4 and Fig. 5 show that the penetration of coal-carbon dust is on the average about 30% lower than for atmospheric dust. Part of this difference is because laboratory atmospheric dust is finer than average, and part be-

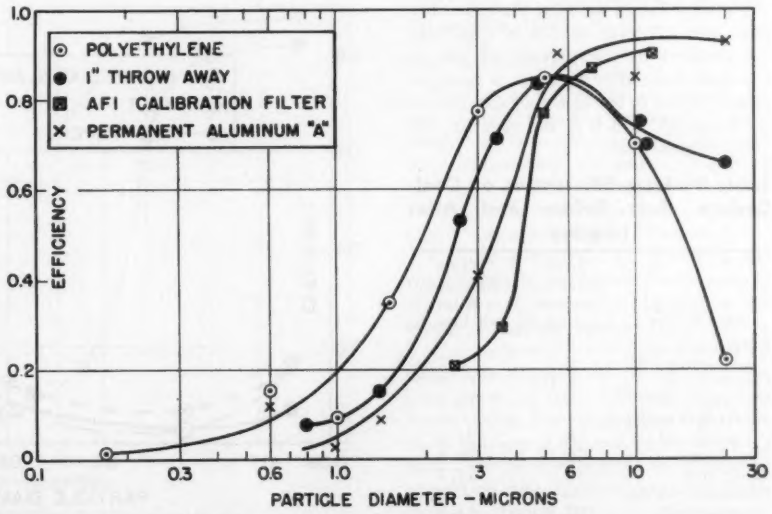


Fig. 14. Fractional efficiency of four roughing filters.

cause coal-carbon dust is coarser in particle size than average atmospheric dust.

Pressure drops and weight efficiencies versus load in grams per square foot of nominal air cleaner area are presented in Figs. 6 to 10. A number of observations on the factors affecting the loading of air cleaners can be made from these figures and from observations made during the test runs. The loading characteristics of high velocity panel filters such as the AFI, polyethylene, permanent aluminum "A," the foam filters and the throw-away filters, Figs. 6, 7, and 8, are determined primarily by the surface characteristics of the filter. Thus the pressure drop of the polyethylene filter, which has a surface of smooth woven plastic fibers, increased very rapidly due to the formation of a smooth tight lint layer on the surface, whereas the pressure drop of the AFI filter increased much more slowly due to coarse, corrugated metal screen on the front surface. Similarly, the principal reason for the greater increase of pressure drop of the one-inch throw-away as compared to the two-inch throw-away was that the denser surface obtained by compressing the media to a one-inch thickness permitted a smooth tight lint layer to form.

Comparison of the pleated cloth mat, Fig. 9, and the electrified media, Fig. 10, is more difficult because the actual media areas are different and the loading of the highly pleated electrified media occurred across the edge of the pleats. The initial decrease in efficiency of the electrified media, Fig. 10, occurs because the dust load progressively shunts the potential across the media. The efficiency rises again due to the buildup of the lint mat on the filter surface. The electric potential is completely ineffective in the loaded filter in that the power on weight efficiency is the same as the power off efficiency.

Figure 3 shows that the dust load per unit area of filter media is relatively independent of the percent of lint in the dust if the filter fiber size is approximately equal to the lint fiber size (about six microns), which is the case for the $^1/_2$-inch glass mat.

Table II—Stain Efficiencies on Coal-Carbon Dust Before and After Loading

Air Cleaner	Stain Efficiency Before Loading, %	Stain Efficiency After Loading, %
Permanent aluminum "A"	0.1	6.7
Coarse foam	1.0	15.0
Polyethylene	3.7	15.1
Electrified media (power off)	8.4	57.2
Fine foam	10.8	38.6
Cloth mat	11.2	41.7
Electrified media (power on)	62.9	61.5

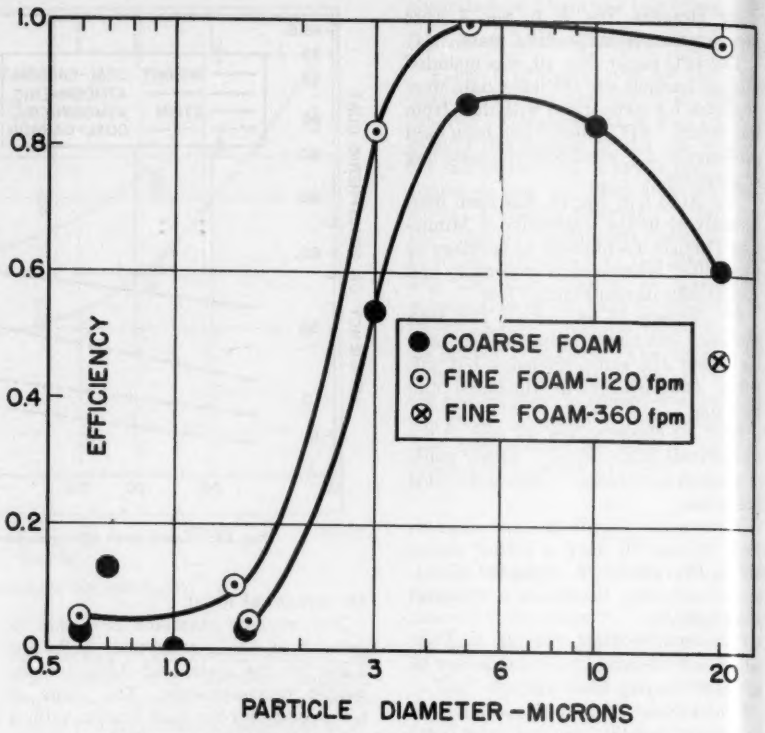


Fig. 15. Fractional efficiences of coarse and fine urethane foam air filters.

Comparisons of the stain efficiency on coal-carbon dust before and after loading are given in Table II.

Correlation of Clean Air Cleaner Efficiency on Atmospheric and Coal-Carbon Dust with Filter Mat Parameters

As seen from equation (3) the overall efficiency of a filter is related to the single fiber efficiency and solidarity factor.

Examination of filtration theory reveals that the collection efficiency of the single fiber is made up of contributions from inertial impaction, diffusion, and interception. While these mechanisms will not be discussed here, a brief consideration of the functional form of each reveals the most important variables.

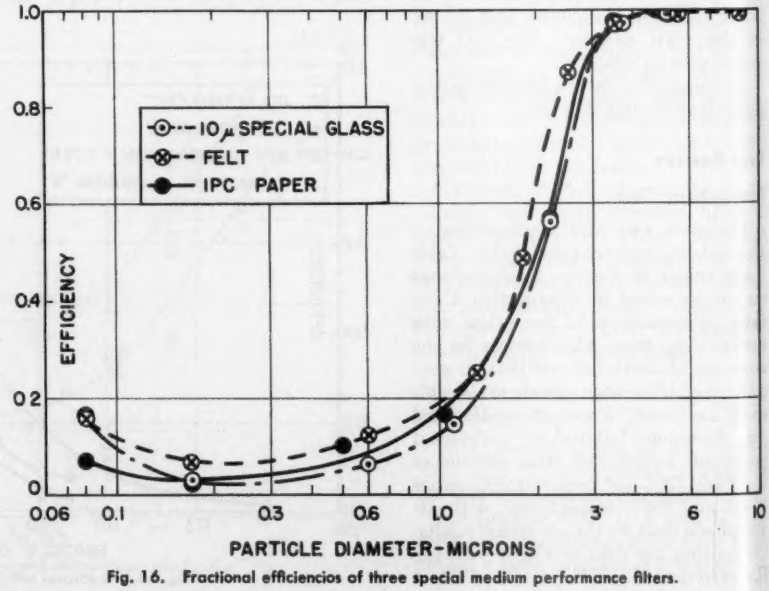


Fig. 16. Fractional efficiencies of three special medium performance filters.

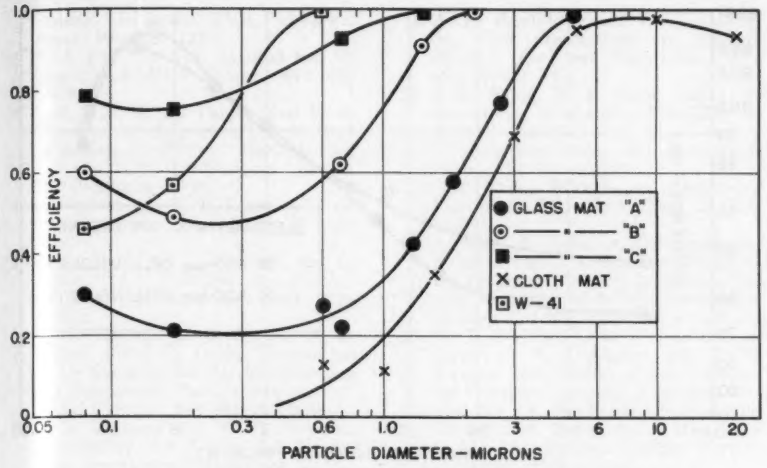


Fig. 17. Fractional efficiency of five medium to high performance air filters.

Impaction:

$$\eta_{sp} = f(N_0, N_{Re}) \quad (4)$$

Interception:

$$\eta_{si} = f(R, N_{Re}) \quad (5)$$

Diffusion:

$$\eta_{sd} = f(N_{Re}, N_{Pe}) \quad (6)$$

where:

$$N_D = \left(\frac{C\rho_p V_0}{18\,\mu_g D_f}\right)^{1/2} Dp \quad (7)$$

$$N_{Re} = \frac{\rho_g D_p V_0}{\mu_g} \quad (8)$$

$$R = \frac{D_p}{D_f} \quad (9)$$

$$N_{Pe} = \frac{V_0 D_f}{D_{BM}} \quad (10)$$

$$S_f = \frac{4}{\pi}\,\frac{w}{\rho_f D_f} \quad (11)$$

Equations (4 to 11) show that in addition to S_f the most important filter parameters are the fiber size, D_f, the media velocity, V_0, and the particle size, D_p. The relationship of the over-all filter efficiency on a dust of broad and arbitrary size distribution to these parameters is complex and will be different for each of the filters included in this study. After a consideration of this problem, the ratio $S_{fe}D_{fe}^{-1/2}$ was chosen as the parameter against which to correlate the over-all efficiencies of the filters on atmospheric and coal-carbon dust. The media velocity, V_0, was not included because the filters were tested at only one velocity corresponding to that which would normally be used in service. Thus filters of a given efficiency were all tested at nearly the same velocity.

In Figs. 11 and 12, the stain and weight efficiencies on atmospheric and coal-carbon dusts are plotted against $S_{fe}D_{fe}^{-1/2}$. Except for filters Nos. 19 and 20, for which the air flow technique for measuring fiber size would not be expected to be valid because of fiber shape, the electrified media with power on, No. 27, and medias Nos. 12, 13, and 21, which have α's exceeding 0.1, it can be seen that there is a fair correlation between S_{fe} $D_{fe}^{-1/2}$ and the efficiency. The correlation is not as good for atmospheric dust as for coal-carbon dust because of the greater variability in particle size distribution.

If the mean lines of the data for each dust are replotted on a single plot (Fig. 13) several things are apparent. First, the shape of the four curves is essentially the same. This is probably due to the similarity in size distribution of the coal-carbon and atmospheric dusts. However, the lower efficiency on atmospheric dust indicates that its average particle size is smaller than the coal-carbon dust. Second, it is noteworthy that pronounced bends in the curves occur at S_{fe} $D_{fe}^{-1/2} = 500$. This indicates that the differences in the clean efficiencies of commercial filters having $S_{fe}D_{fe}^{-1/2}$ less than 500 are relatively small when operated at rated conditions.

If S_{fe} and D_{fe} are known it is possible to use Fig. 13 to estimate the filter efficiency. Conversely, the D_{fe}, S_{fe}, and w of a filter having a known efficiency can be calculated from equation (2) and Fig. 13.

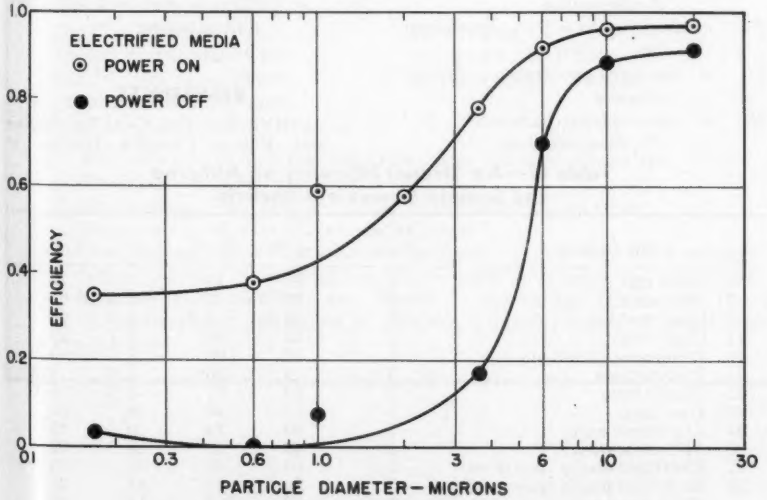


Fig. 18. Fractional efficiency of electrified media air cleaner.

Table III—Precision of Fractional Efficiency Measurements

D_p, microns	$s/\bar{P}$, %
0.08	3.5
0.17	3.1
1.6	9.9
1.0	3.0
1.5	5.2
2.2	1.3
3.0	7.5
3.6	5.5
5.0	7.2
10.0	12.0
20.0	7.9

Fractional Efficiencies

The fractional efficiency curves obtained by the use of the homogeneous methylene blue aerosols on 17 different air cleaners are shown in Figs. 14 through 19. The average $s/\bar{P}$ in percent for each particle size summed over-all air cleaners is given in Table III.

It is likely that the variations in $s/\bar{P}$ with size result from the different sample evaluation techniques used and from the effects of particle bounce.

The shape of the curve for a given air cleaner is determined by the relative importance of the different filtration mechanisms. For example, on Fig. 16 the steep portion of the curves between 1.5 and three microns results from inertial impaction, the flattened portion of the curves between 0.3 and one micron,

from interception, and the rise in efficiency below 0.3 micron, from diffusion.

The drop in efficiency of the high velocity filters above about five microns is apparently due to particle bounce. From Fig. 14 it will be noted that the drop is the greatest for the dry polyethylene, moderate for the partially coated throw-away, and negligible for the heavily oiled AFI and aluminum air cleaners. The particle bounce effect is dependent upon velocity as shown in Fig. 15. Increasing the velocity for the fine foam air cleaner from 120 to 360 fpm decreased the efficiency from 97 to 47% or an 18-fold increase in penetration. The bounce effect, however, is not restricted to fibrous filters. From Fig. 19 it can be seen that the penetration through the electrostatic air cleaner increased 10-fold in going from seven to 12 microns even though the collection plates were adhesive coated. Thus it appears that the collection efficiency of air cleaners on particles above about five microns is highly dependent on the media velocity and adhesive used.

Bacteria Tests

The results of the bacteria efficiency tests are shown in Table IV. In addition to the efficiency, the standard deviation in percent, s, and $s/\bar{P}$ in percent are given. Because of the variability of the data, the conclusions here drawn are that the efficiency on airborne bacteria is a little greater than the weight efficiency on natural atmospheric dust.

Conclusions

Although the primary purpose of this paper is the presentation and not the interpretation of the performance data, there are several conclusions that may be stated.

1 The use of the other test methods and aerosols would certainly change both the general magnitude of the results and the relative ranking of some of the air cleaners. However, it is believed that these data give a reasonable indication of the performance capabilities of the various types.

2 This study has demonstrated that the test methods and aerosols used here can be applied over a broad range of air cleaner performance.

3 Measurement of the fractional efficiency curves of air cleaners using homogeneous dye aerosols is possible on almost any size and type of air cleaner.

4 The correlation of the clean efficiencies of the filters with the parameter $S_{f_e} D_{f_e}^{-\frac{1}{2}}$ shows that filters with a value of the parameter less than 400 have about the same efficiencies. This implies that there are no magic filter configurations or fiber materials, but that the efficiency of a filter depends upon the size and amount of fibers.

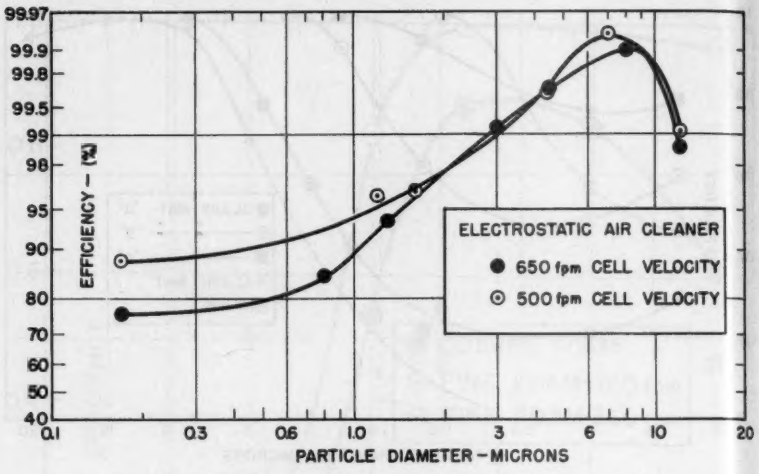


Fig. 19. Efficiency of a two-stage electrostatic air cleaner.

5 The loading characteristics of a filter depend upon the surface of the filter on which the lint mat forms. A filter with a smooth, tight surface loads more rapidly than one with a rough surface.

6 The clean efficiency of a filter on particles larger than five microns is highly dependent upon the media velocity and the adhesive.

List of Symbols

C = Cunningham's correction, dimensionless
D_{BM} = Particle diffusion coefficient, cm²/sec
D_f = Fiber diameter, cm or microns
D_{f_e} = Effective fiber diameter measured by air flow technique, cm or microns
D_p = Particle diameter, microns
L = Filter thickness, cm
N_D = Impaction parameter, $[c\rho_p V_0/18\,\mu_g D_f]^{1/2} D_p$, dimensionless
N_{Pe} = Peclet number, $V_0 D_f / D_{BM}$, dimensionless
N_{Re} = Reynolds number, $\rho_g D_p V_0/\mu_g$, dimensionless
P = Penetration $= 1 - \eta$, dimensionless
$\bar{P}$ = Average penetration, dimensionless
R = Interception parameter, D_p/D_f, dimensionless
S_f = Solidarity factor, dimensionless
S_{f_e} = Effective solidarity factor measured by air flow technique, dimensionless
V_0 = Free stream air velocity, cm/sec or ft/min
Δp = Pressure drop across filter, In. W.G. H_2O
s = Standard deviation, dimensionless
w = Weight per unit surface area, gm/cm³
α = Fiber volume fraction, dimensionless
η = Efficiency, dimensionless
η_s = Single fiber efficiency, dimensionless
η_{sd} = Single fiber diffusion efficiency, dimensionless
η_{si} = Single fiber interception efficiency, dimensionless
η_{sp} = Single fiber impaction efficiency, dimensionless
μ_g = Air viscosity, poise
ρ_f = Fiber density, gm/cm³
ρ_g = Air density, gm/cm³
ρ_p = Particle density, gm/cm³
σ_g = Geometric standard deviation, dimensionless

REFERENCES

1. "ASHVE Standard Code for Testing and Rating Cleaning Devices in

Table IV—Air Cleaner Efficiency on Airborne and Serratia Marcescens Bacteria

	Air Cleaner	No. of Runs	η, %	$\bar{P}$, %	s, %	$s/\bar{P}$, %
1	Glass mat A	3	86	14	4.1	29
2	Glass mat B	3	89	11	6.6	60
3	Glass mat C	3	92.3	7.7	4.9	64
11	Cloth mat	3	62	38	9.1	24
19	Permanent aluminum A	2	32	68	3.5	5.2
21	Polyethylene	3	44	56	2.4	4.3
22	Coarse foam	3	39	61	3.4	5.6
23	Fine foam	3	51	49	43	88
24	1 in. throw-away	5	66	34	9.5	28
26	AFI calibration	3	42	58	13	22
27	Electrified media (power on)	3	60	40	22	36
28	Electrified media (power off)	3	39	61	12	30
	100% penetration	5	−12	112	14	13

General Ventilation Work," *ASHVE Trans.* **39**: 225 (1933).
2. R. S. Dill, "A Test Method for Air Filters," *ASHVE Trans.* **44**: 379 (1938).
3. R. S. Farr, W. M. Pauley, and K. A. Crisman, "An Improved Test Method for Rating Air Filters," *Heating, Piping and Air Conditioning*, **20**: 2, 111 (February 1948).
4. A. Nutting and R. F. Logsdor, "New Air Filter Code," *Ibid.*, **25**: 6, 77 (June 1953).
5. P. L. Magill, F. R. Holden, and C. Ackley, "Air Pollution Handbook," McGraw Hill Book Company, Inc. (1956).
6. K. T. Whitby, A. B. Algren, R. C. Jordan, and J. C. Annis, "Evaluation of Air Cleaners for Air Conditioning and Ventilation, Part I—Apparatus," *ASHAE Trans.* **64**: 401–20 (1958).
7. E. N. Hellberg and W. R. Nehlsen, "Ventilation Air Filters 0-5 Micron Dust Arrestance," Technical Memorandum M-099, U. S. Naval Civil Engineering Research and Evaluation Laboratory, Port Hueneme, California (1955).
8. T. E. Wright, R. J. Stasny, and C. E. Lapple, "High Velocity Air Filters," WADC TR 55-457 or ASTIA No. AD-142075 (October 1957).
9. A. E. Humphrey and E. L. Gaden, Jr., "Air Sterilization by Fibrous Media," *Ind. and Eng. Chem.*, **47**: 924 (1955).
10. J. B. Wong, W. E. Ranz, and J. F. Johnstone, "Collection Efficiency of Aerosol Particles and Resistance to Flow through Fiber Mats," *J. Appl. Phys.*, **27**: 161 (1956).
11. C. Y. Chen, "Filtration of Aerosols by Fibrous Media," *Chem. Revs.*, **55**: 595 (1955).
12. S. Stern, S. Jones, A. Schekman, R. Stuart, "Upper Atmosphere Monitoring Program," General Mills Inc., Report No. 1863, to A.E.C. Division of Biology and Medicine (June 1958).
13. K. T. Whitby, A. R. McFarland, A. Kydd, D. A. Lundgren, and R. C. Jordan, "Evaluation of Air Cleaners for Occupied Spaces," Technical Report No. 14, Mechanical Engineering Department, University of Minnesota to U. S. Public Health Service (February 1961).
14. A. B. Algren, K. T. Whitby, R. C. Jordan, and J. C. Annis, "Review of Air Cleaning Research," Mechanical Engineering Department, University of Minnesota (1959).
15. K. T. Whitby, D. A. Lundgren, and R. C. Jordan, "Homogeneous Aerosol Generators," Technical Report No. 13, Mechanical Engineering Department, University of Minnesota to U. S. Public Health Service (February 1961).
16. "Methylene Blue Particulate Test for Respirator Canisters," British Standards 2577, B.S.I., 2 Park St., London W. 1. (1955).
17. K. T. Whitby, A. R. McFarland, and D. A. Lundgren, "Generator for Producing High Concentrations of Small Ions," Technical Report No. 12, Mechanical Engineering Department, University of Minnesota to U. S. Public Health Service (July 1960).
18. R. Dennis, L. Silverman, C. Billing, D. Anderson, W. Samples, H. Donaldson, Jr., and P. Drinker. A.E.C. NYO-4611 on Air Cleaning Studies, Harvard Air Cleaning Laboratory (October 1956).
19. A. B. Algren, K. T. Whitby, and J. C. Annis, "Evaluation of Methods and Apparatus for Life Testing," Technical Report No. 10, Mechanical Engineering Department, University of Minnesota to U. S. Public Health Service (May 1959).
20. K. T. Whitby, A. B. Algren, R. C. Jordan, and J. C. Annis, "The ASHAE Airborne Dust Survey," *ASHAE Trans.*, **64**: 129 (1958).

OPEN FOR SUGGESTIONS

The time is fast approaching when a new president and six new APCA Directors will be elected by the membership. You, as an individual member or company representative member of APCA, are requested to submit to the chairman or any member of the Nominating Committee, names of individuals and the offices for which you feel they are qualified. These recommendations should be received before March 1, 1962.

The members of the Nominating Committee and their addresses are as follows:

V. G. MacKenzie, Chairman
Chief, Division of Air Pollution
U. S. Dept. of HEW
Public Health Service
Washington 25, D. C.

Dr. C. A. Bishop
United States Steel Corp.
525 William Penn Place
Pittsburgh, Pennsylvania

L. B. Hitchcock
Lauren B. Hitchcock Assoc.
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H. M. Pier
9 Sunnybrook Road
Basking Ridge, New Jersey

F. R. Rehm
Department of Smoke Regulation
Milwaukee, Wisconsin

V. H. Sussman
Dept. of Health
Chief,
Air Pollution Control Section
Div. of Industrial Hygiene
P. O. Box 90
Harrisburg, Pa.

The offices for which this committee is to select nominees are:

1. President—to serve one year.
2. Six Directors—to serve according to the following schedule:
   Two control officials to serve three years.
   One representative from research, educational, and consultant category to serve three years.
   Three industry representatives, two to serve three years and one to serve one year.

Retiring Board members are: Harry A. Belyea and Charles W. Gruber, control officials; R. L. Ireland, L. W. Cadwallader, and Roger W. Hooker, industry; and V. G. MacKenzie, research, educational, and consultant category.

A COMPARISON of Various SOURCES of Automotive EMISSIONS*

HERBERT C. McKEE and KENNETH D. MILLS, Southwest Research Institute, San Antonio, Texas

The importance of automobile exhaust as an atmospheric pollutant has been recognized for several years. Extensive investigations have been conducted to determine the amounts of various contaminants and their compositions. The photochemical reactions which take place in the atmosphere have also been studied to determine how exhaust constituents are converted into other products which cause eye irritation, vegetation damage, and other undesirable manifestations of the characteristic oxidizing type smog.

More recently, attention has been directed to other sources of hydrocarbon emissions from automobiles including crankcase and carburetor evaporation losses. Only a limited amount of work has been conducted to ascertain the extent of these emissions.

This program was undertaken to investigate all normal sources of hydrocarbon emissions from automobiles. Special emphasis was placed on crankcase fumes and carburetor evaporation losses since much less information is available concerning these emissions. Exhaust emissions were also measured in order to provide a basis for comparison. Consideration was also given to evaporation losses from the fuel tank of an automobile since this factor also has not been investigated in any detail.

Experimental Procedures

Vehicles

Makes and models of vehicles were selected which would represent as nearly as possible the California automobile population as indicated by a study of the 1959 California Passenger Car Registrations.[1] Selection was also made insofar as possible to incorporate a wide variety of engine and carburetor configurations.

Data on the five vehicles used in this study are presented in Table I. With only one exception, all vehicles were in good mechanical condition and were given an electrical and fuel system tune-up prior to testing. The single exception was the 1957 Chevrolet which was evaluated under a greater variety of conditions, and was procured specifically for that purpose. It originally was in very poor mechanical condition and required not only ignition and fuel system maintenance but also a major overhaul. It was tested in three conditions: (*1*) as received, (*2*) after major overhaul, typifying an engine in sound mechanical condition but in need of thorough tune-up, and (*3*) after major overhaul and complete tune-up.

Preparation for tests included also the installation of the apparatus and instrumentation necessary for sampling and analysis of the emissions.

Vehicle Operation

Most of the sampling and analysis was accomplished during vehicle operation involving a variety of conditions. A driving cycle was developed, based on the legal standards adopted by the California State Board of Health to evaluate exhaust control devices. The specific cycle which was adopted from that pattern required approximately 15 minutes for completion and consisted of 47 maneuvers. This test cycle is presented in Table II.

Road operation was conducted on an asphalt farm road adjacent to Southwest Research Institute, near San Antonio, Texas. The traffic count was extremely low so that minimum interference was encountered during test operation. The terrain was moderately rolling, however, which resulted in a minor variation in the over-all time required to complete an integrated driving cycle.

Much of the operation was conducted on a chassis dynamometer to permit a comparison of emission data under road operation with dynamometer operation, to provide more nearly constant speed and load conditions, and also to permit installation of sample mixing and analysis equipment adjacent to the dynamometer so that instrument operation would not be affected by vibration and the lack of a stable electrical power source. The same integrated driving cycle was employed during chassis dynamometer operation; however, a fixed dynamometer loading was established so that a good degree of repeatability existed among individual runs.

All operation during sampling and analysis was conducted on two specially blended test fuels: one designated Fuel "A" had a nominal vapor pressure of 6.5 lb Reid and 20 bromine number; the other, Fuel "B," had a nominal vapor pressure of 8.5 lb Reid and a 30 bromine number.

Instrumentation

Analysis of the various emissions was accomplished with a Flame Ionization Analysis Detector (FIAD) manufactured by the Carad Corporation, and for comparative purposes a Liston-Becker Model 15A Infrared (IR) Gas Analyzer sensitized with hexane. The output of both instruments was fed into Varian Model G11A Strip Chart Recorders.

In all instances, samples drawn from the various sources were passed through a dilution panel which provided the required sample dilution for analyzer sensitivity and air and hydrogen for the FIAD. Figure 1 shows a schematic diagram of the sampling and analytical

Table I—Vehicle Description

Make	Model	Engine	Compression Ratio	Carburetor
Chevrolet	1957	283-V8	9.5:1	4-barrel rochester 2-barrel rochester
Chevrolet	1955	2355-6 cyl	7.5:1	1-barrel rochester
Ford	1956	292-V8	8.4:1	4-barrel holley
Buick	1958	364-V8	9.5:1	2-barrel stromberg
Plymouth	1958	318-V8	9.0:1	2-barrel carter BBS

* Presented at the 54th Annual Meeting of APCA, Commodore Hotel, June 11–15, 1961, New York, New York.

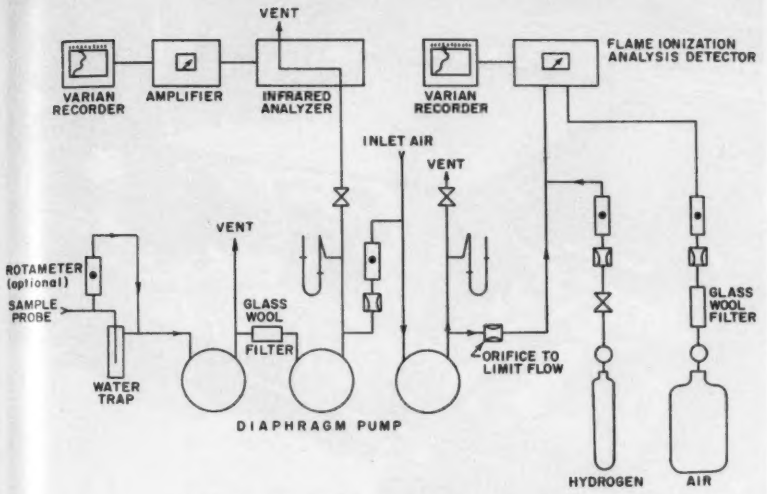

Fig. 1. Schematic diagram of sampling system.

equipment and Fig. 2 shows the actual equipment installed adjacent to the chassis dynamometer. Both analytical instruments were calibrated with n-hexane.

Exhaust flow was measured with orifice meters, equipped with Statham pressure transducers operating in conjunction with a Texas Instruments Servoriter variable strip chart recorder.

Road draft tube flow rates were measured with a General Controls venturi meter, together with one of the transducers and recorder used for exhaust flow measurement. The venturi meter was sized so that back pressure on the road draft tube would be limited to less than 0.05 inch of water. In addition, ventilation of the crankcase was aided on some runs by the use of an auxiliary blower which increased the air flow rate through the crankcase and out the road draft tube. It was found that total emissions from the road draft tube were approximately the same whether this blower was used or not, and therefore it was assumed that the effects of back pressure from the venturi on the total emissions from the crankcase were negligible.

To measure carburetor evaporation losses, both during vehicle operation and during the "hot soak" period after shutdown, an auxiliary shroud or housing was constructed to enclose the entire carburetor and air cleaner assembly. One typical assembly of this type is shown in Fig. 3. Air was passed through this housing and withdrawn by a suction pump to provide a constant flow of purge air for analysis. The opening at the front of the housing was large enough to admit air for the engine intake in addition to the purge air pulled through by the pump. By monitoring this purge air, it was possible to measure rates of evaporation irrespective of the method of loss from the carburetor or air cleaner. This was considered essential because it was anticipated that carburetors with only internal vents, as well as those with external vents, might permit escape of fuel which evaporates in the float chamber. If evaporated fuel were to escape from a carburetor with no external vents, the escape passages could be, singly or in combination, at the throttle shaft, through gaskets and joints, and through the air horn and air cleaner. Thus, regardless of the route by which vapor escaped, it would escape into the housing and be drawn past the analytical instrument by the stream of purge air. A housing designed to permit normal functioning of the carburetor including provision for adequate inlet air and also purge air for sampling would furnish a single sample source for the measurement of total evaporation losses from the carburetor. Purge air rates were selected to provide approximately one change of air within the housing per minute, exclusive of air used for engine operation. This rate was thought to be large enough to prevent an undue accumulation of vapor inside the housing, and still small enough to prevent the creation of aerodynamic flow which might cause aspirating effects or other undesirable effects which could influence the rate of evaporation loss and give inaccurate results.

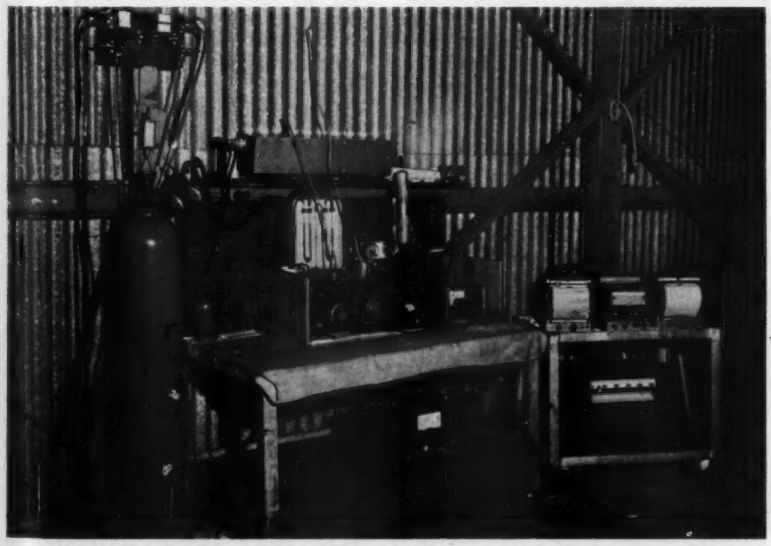

Fig. 2. Sampling and analytical equipment installed adjacent to chassis dynamometer.

TABLE II—Integrated Driving Cycle[a]

Maneuver, Mph	Acceleration Rate, Ft/sec²	Maneuver, Mph	Acceleration Rate, Ft/sec²
0–25	3.2	30–0	−3.7
25–20	—	0–25	3.2
20	Cruise	25–30	—
20–15	—	30	Cruise
15–30	1.8	30–15	−2.0
30–15	−2.0	15–30	1.8
15–30	1.8	30–15	−2.0
30	Cruise	15–30	1.8
30–0	−3.7	30–40	—
0–25	3.2	40	Cruise
25–30	—	40–50	—
30–15	−2.0	50	Cruise
15–30	1.8	50–20	1.8
30	Cruise	20–15	—
30–0	3.7	15–30	1.8
0	Idle	30–40	—
0–25	3.2	40	Cruise
25–20	—	40–50	—
20	Cruise	50	Cruise
20–15	—	50–20	1.8
15–30	1.8	20–15	—
30	Cruise	15–30	1.8
30–15	−2.0	30–0	−3.7
15–30	1.8	0–50	Max.

[a] Based on legal standards adopted by the State of California, and reported in: J. A. Maga and G. C. Haas, "The Development of Motor Vehicle Exhaust Emission Standards in California," *J. Air Poll. Control Assoc.*, **10**: 5, 393–96 (October 1960).

Results and Discussion

Exhaust Emissions

The exhaust emissions as shown in Table III were calculated for each test from recorder charts indicating hydrocarbon concentration, exhaust flow, and temperature. The concentration was measured continuously by the FIAD during vehicle operation and the average concentration was determined by integrating the area under the curve on the recorder chart with a planimeter, for the entire integrated driving cycle. Total flow during the integrated cycle was determined by stepwise calculation based on the differential pressure chart from the orifice meter, correcting the indicated value for the average temperature since the calibration of the orifice meter depended on temperature. The product of the average concentration and the total flow corrected to 60°F and atmospheric pressure gave the total exhaust emission for the complete operating cycle.

It is believed that the measurement of total exhaust emission during a complete integrated driving cycle by the technique described above offers considerable advantage compared to the analysis of individual samples obtained under different driving conditions. In many previous investigations separate measurements were made under different conditions of idle, cruise, acceleration, and deceleration, and the analytical results for these individual measurements were used to calculate an over-all emission rate based on the percentage of total driving time assumed to be composed of the various modes of operation. The "integrated cycle" is preferable because the emissions at any particular moment are affected not only by the operation at that moment but by the preceding maneuvers. Thus, a cruise sample obtained at 40 mph shortly after a rapid acceleration from 0 to 40 might be expected to show concentrations different from another 40 mph cruise sample obtained immediately after a deceleration from 60 to 40.

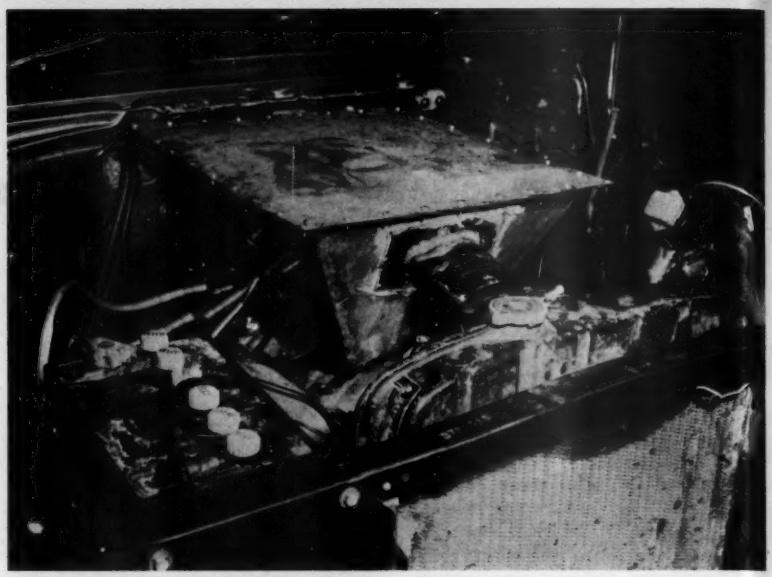

Fig. 3. Typical installation of housing around air cleaner and carburetor.

Other factors of engine and automobile operation also affect the results of a sample and cannot be adequately controlled under experimental conditions to be sure that single samples are representative of all operations at a given condition.

Another example of the advantage of obtaining results from an integrated driving cycle is evident from Fig. 4, which shows the actual record obtained in two different tests. In the Chevrolet with a standard transmission, the acceleration periods show the effect of manual shifting of gears, with a small peak after each change as the driver shifted from low to second to high. This was not noticed on cars equipped with automatic transmissions, although it is suspected that similar though smaller effects may exist which were not measured because of the 10 to 12 second time lag inherent in the sampling system. Such effects cannot be considered adequately in the calculation of an over-all value based on individual samples, but are automatically included in the results obtained from an integrated driving cycle.

Crankcase Emissions

Emissions from the crankcase were determined by calculating the total emissions during an integrated driving cycle in the same manner as that used to determine exhaust emissions. Figure 5 shows a typical chart obtained during one of the 15-minute integrated driving cycles.

The data summarized in Table IV include the total emission and the percent of the total which was emitted from the crankcase. Of the various vehicles tested, the Ford showed the highest percentage of crankcase emission. The manifold heat control valve in this car was stuck in the closed position, resulting in a very low flow rate through the right exhaust and perhaps an abnormal blowby emission rate. Apart from this vehicle the highest crankcase emission shown was that of the Plymouth.

Crankcase emissions from the 1957

Table III—Exhaust Emissions

Vehicle and Condition	Average Emissions from All Sources,[a] Lb/hr	Average Exhaust Emissions		Average Fuel Consumption	Average Emissions from All Sources, Percent of Fuel Burned	Average Exhaust Emissions, Percent of Fuel Burned
		Lb/hr	Percent of Total			
1957 Chev V-8 station wagon, as received	4.70	4.04	86.1	—	—	—
1957 Chev V-8 station wagon, overhauled and adjusted	1.35	1.11	82.3	19.36	6.9	5.7
1957 Chev V-8 station wagon, 2 bbl carburetor	0.88	0.73	83.4	14.59	6.0	5.0
1955 Chev 6-cylinder	0.68	0.43	63.9	9.49	7.1	4.6
1958 Buick V-8	0.77	0.60	78.3	13.20	5.8	4.5
1956 Ford V-8	0.82	0.49	59.4	11.72	7.0	4.1
1958 Plymouth	0.57	0.37	63.6	10.88	5.3	3.4

[a] Excluding hot soak and fuel tank losses.

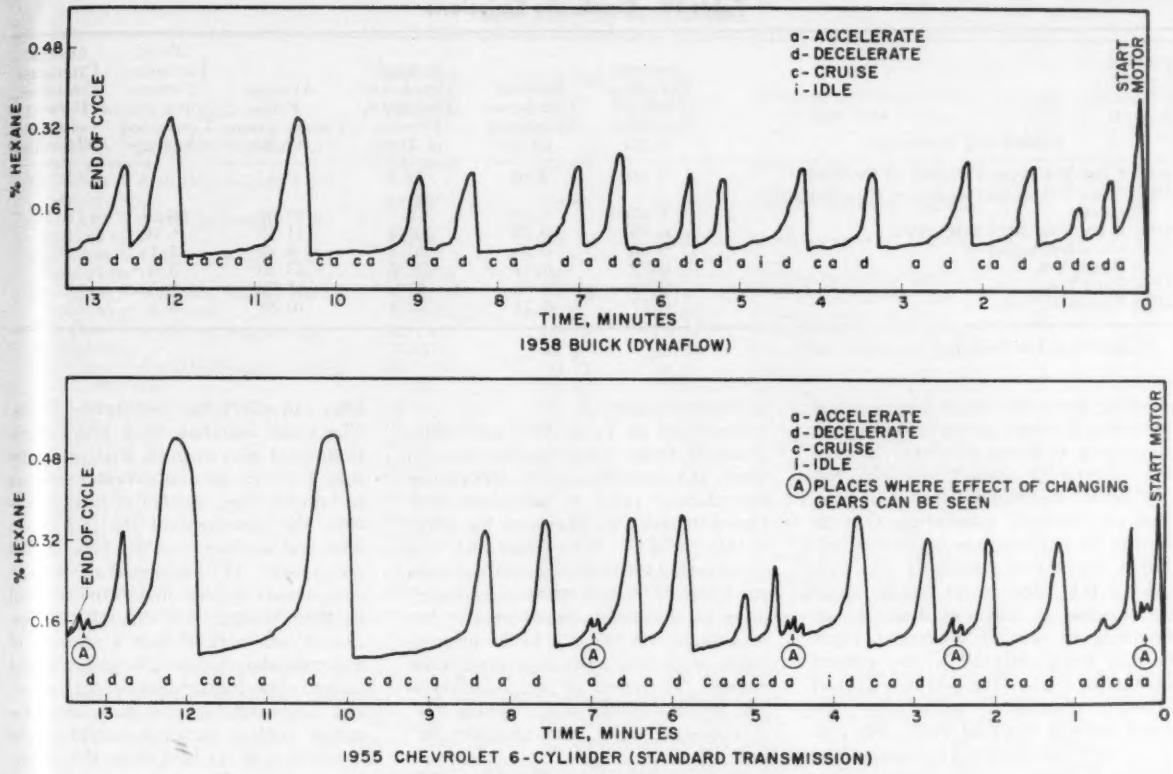
a - ACCELERATE
d - DECELERATE
c - CRUISE
i - IDLE
START MOTOR
END OF CYCLE
% HEXANE
0.48
0.32
0.16
a d a d c a c a d c a c a d a d c a d a d c a d c d a i d c a d a d c a d a d c d a
13 12 11 10 9 8 7 6 5 4 3 2 1 0
TIME, MINUTES
1958 BUICK (DYNAFLOW)
a - ACCELERATE
d - DECELERATE
c - CRUISE
i - IDLE
(A) PLACES WHERE EFFECT OF CHANGING GEARS CAN BE SEEN
START MOTOR
END OF CYCLE
% HEXANE
0.48
0.32
0.16
d d a d c a c a d c a c a d a d a d a d a d c a d c d a i d c a d a d c a d a d c d a
13 12 11 10 9 8 7 6 5 4 3 2 1 0
TIME, MINUTES
1955 CHEVROLET 6-CYLINDER (STANDARD TRANSMISSION)

Fig. 4. Exhaust concentrations during integrated driving cycle.

Chevrolet when operated in "as is" condition, appeared unreasonably low on a percentage basis. This vehicle was originally in very poor condition with respect to both engine wear and ignition adjustment. In comparison with other cars and the same car after it was repaired and tuned up, the exhaust emissions were disproportionately high. This high value for exhaust emissions gives a lower relative value for crankcase emissions on a percentage basis. It is therefore much more important to consider the actual values in this instance, and to note the apparent influence of engine condition on both blowby and exhaust emissions. The 19.5% of total emissions from the crankcase, obtained with the same vehicle after overhaul and tune-up, appears more nearly representative of an engine in an average to good condition.

Since most of the results were obtained during operation on an integrated driving cycle, it was decided that crankcase and exhaust emission should be measured under constant cruise conditions for comparison. Therefore, additional runs were made with the Buick during which both crankcase and exhaust emissions were measured at 30 and 50 mph cruise. The results (Table V) indicate that the relative percentage of emission from the crankcase is considerably higher under these conditions than during operation over an integrated driving cycle. This further points out the desirability of continuously analyzing samples during such a cycle. With the crankcase emissions as with the exhaust, the effect of previous operating cycles on the values obtained at a given moment was obvious although less pronounced.

Carburetor Evaporation Losses

Running Losses

Table VI shows the carburetor evaporation losses while the vehicles were running. Within the scope of this program, no significant differences in running losses by fuel evaporation were noted with carburetors using different venting systems. As can be seen, the amount of fuel evaporated from the carburetor during running is quite low, compared to the exhaust and crankcase emissions.

Under higher speed conditions characteristic of highway operation, air flow over the engine and the rate of fuel supply to the carburetor appear to be adequate under normal conditions so as to preclude extensive evaporation in the float chamber of a carburetor under normal conditions. Vapor from such evaporation as does occur is probably drawn into the carburetor in most instances, thus giving a slight enriching effect but preventing the escape of fuel vapor to the atmosphere.

Hot Soak Losses

Losses of hydrocarbon vapor from the carburetor by evaporation immediately after engine shutdown were measured to obtain data on the amount of hydrocarbons lost to the atmosphere in this manner. While such losses, of course, are not directly related to losses while driving, the usual pattern of stop-and-go driving typical of urban areas presents many opportunities for hydrocarbon emission in this manner.

Hot soak losses were measured by

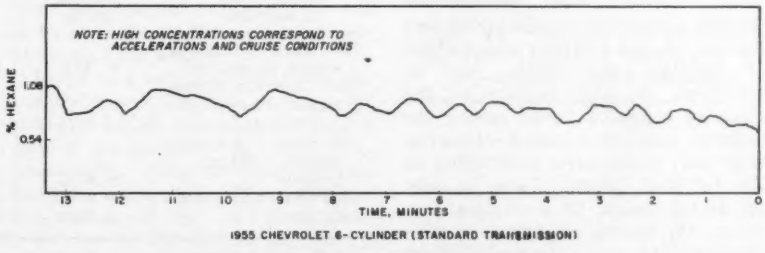
NOTE: HIGH CONCENTRATIONS CORRESPOND TO ACCELERATIONS AND CRUISE CONDITIONS
% HEXANE
1.08
0.54
13 12 11 10 9 8 7 6 5 4 3 2 1 0
TIME, MINUTES
1955 CHEVROLET 6-CYLINDER (STANDARD TRANSMISSION)

Fig. 5. Crankcase ventilator concentrations.

Table IV—Crankcase Emissions

Vehicle and Condition	Average Emissions from All Sources,[a] Lb/hr	Average Crankcase Emissions, Lb/hr	Average Crankcase Emissions, Percent of Total	Average Fuel Consumption, Lb/hr	Total Emissions, Percent of Fuel Consumed, Average	Average Crankcase Emissions, Percent of Fuel Consumed
1957 Chev V-8 station wagon, as received	4.70	0.65	13.9	—	—	
1957 Chev V-8 station wagon, overhauled and adjusted	1.35	0.24	17.7	19.36	6.9	1.2
1957 Chev V-8, 2 bbl carburetor	0.88	0.15	16.6	14.59	6.0	1.0
1955 Chev 6-cylinder	0.68	0.24	36.0	9.49	7.1	2.5
1958 Buick V-8	0.77	0.17	21.7	13.20	5.8	1.3
1956 Ford V-8	0.82	0.33	40.6	11.72	6.0	2.8
1958 Plymouth V-8	0.57	0.21	36.4	10.88	5.3	1.9

[a] Excluding hot soak and fuel tank losses.

shutting down the engine after a period of driving to attain normal temperature, continuing to sweep air slowly through the housing or shroud over the carburetor for an extended period of time, and continuously monitoring this air stream for hydrocarbon vapor content. For a number of reasons it was considered that more valid results would be obtained in this way than by attempting to remove condensed vapor in cold traps attached to the various carburetor vents. The cold trap method appears reasonably satisfactory for losses through external vents, but presents difficulties in studying carburetors equipped with internal vents. Connection of a cold trap to an internal vent is difficult from an operational standpoint and may also produce erroneous data. There is a possibility that some of the vapor which passes through an internal vent will not be emitted to the atmosphere but will stay inside the induction system, to be sucked into the carburetor when the engine is again started. This, of course, decreases the amount actually lost to the atmosphere. Furthermore, monitoring of only the carburetor vents will not measure losses which might occur because of leakage around the throttle shafts or past the various gaskets. Therefore it was considered that continuous monitoring of the air passed through a housing or shroud over the carburetor offered an advantage in that total losses could be measured regardless of the method by which the vapor escaped from the carburetor into the surrounding atmosphere.

Hot soak losses are tabulated in Table VII. In general, each car was fairly consistent from one run to another. Individual results varied as a function of fuel volatility and method of operation immediately prior to shutdown. As might be expected, the range of emissions varied among the different cars. It is known, of course, that many factors exert an influence on the hot soak losses. These include: (*1*) vehicle design, (*2*) mechanical condition, (*3*) driving conditions prior to shutdown, (*4*) fuel volatility, and (*5*) ambient conditions.

Presented in Table VIII are values obtained from dynamometer runs in which the operation of the automobile immediately prior to shutdown was varied in order to determine the effect of this variable. With either fuel, it is obvious that the more rigorous operating conditions of 50 mph cruise immediately prior to shutdown caused greater hot soak losses, due probably to the accumulation of greater amounts of heat in the engine. The effect of fuel volatility is also evident as the more volatile "B" fuel showed higher losses than the "A" fuel.

During this series with the 1958 Buick, it was also found that on stopping the engine the fuel filter bowl was full, but after 15 to 20 minutes the level would drop to one-half or perhaps one-quarter full. It is believed that this gasoline was in part replenishing that which had evaporated from the carburetor, and that the position of the filter can affect the evaporation losses. The great variation from one vehicle to another also suggests that other design features are important, such as carburetor type, number of float chambers, the placement of the fuel pump lines and strainer, and the type of fuel pump used. The location of all of these components is also important as well as their design; for example, in one case it was noticed that a strainer of approximately three cubic inches liquid capacity was located immediately above and approximately $1/2$ inch from the engine coolant outlet manifold where it would pick up heat from the engine immediately after shutdown. In this way, an additional 0.08 lb of fuel was made available for evaporation and expansion into the carburetor, thence to the atmosphere by way of either external vents or internal vents through the air horn and air cleaner.

The complexity of the many variables involved in determining hot soak

Table V—Comparison of Exhaust and Crankcase Emissions at Constant Speed[a]

	Exhaust		Crankcase		
	Flow, Cfm	Emissions, Lb/hr	Flow, Cfm[b]	Emissions, Lb/hr	Percent of Total
50 mph cruise	58.6	0.389	2.86	0.275	41.4
30 mph cruise	41.4	0.244	2.83	0.219	47.3

[a] Measured on the dynamometer, 1958 Buick V-8.
[b] Crankcase flow includes 1.5 cfm introduced at the breather.

Table VI—Carburetor Running Losses

Vehicle and Condition	Average Emissions from All Sources,[a] Lb/hr	Average Carb Losses Lb/hr	Average Carb Losses Percent of Total	Average Fuel Consumption, Lb/hr	Average Carb Loss, Percent of Fuel Burned
1957 Chev V-8 station wagon, as received	4.7003	0.0013	0.03	—	—
1957 Chev V-8 station wagon, overhauled and adjusted	1.3478	0.0019	0.14	19.36	0.01
1957 Chev V-8 station wagon, 2 bbl carburetor	0.8752	0.0004	0.05	14.59	0.003
1955 Chev 6-cylinder	0.6774	0.0007	0.1	9.49	0.007
1958 Buick V-8	0.7655	0.0002	0.03	13.20	0.002

[a] Excluding hot soak and fuel tank losses.

Table VII—Hot Soak Losses

Vehicle and Condition	Ambient Temp, Wet/dry	Sampling Time, Min	Total Emissions, Lb × 10^{-3}	Driving Conditions Prior to Hot Soak Period	Type Fuel	Average Conc, Percent as Hexane
1957 Chev V-8 station wagon, 4 bbl carb as rec'd	78/91.5	61.9	54.5	Driving cycles on highway	B	1.45
1957 Chev V-8 station wagon, 4 bbl carb as rec'd	69/96	51.6	55.0	Driving cycles on highway	B	1.76
1957 Chev V-8 station wagon, 4 bbl carb as rec'd	73/93	240	76.5	Driving cycles on highway	B	0.51
1957 Chev V-8 station wagon, 4 bbl carb as rec'd	65/88.5	102	66.1	Driving cycles on dyna	B	1.031
1957 Chev V-8 station wagon, after mechanical overhaul	71/81	70.75	53.7	Driving cycles on dyna	B	1.206
1957 Chev V-8 station wagon, after adjustment	76.5/86.5	60.0	45.89	Driving cycles on dyna	B	1.234
1957 Chev V-8 station wagon, with 2 bbl carburetor	60/73	30.75	18.72	Driving cycles on highway	A	0.930
1955 Chev 6-cylinder	77/86	47.0	39.55	Driving cycles on highway	A	1.298
1958 Buick V-8	66.5/94	30.77	30.46	Driving cycles on highway	A	0.366
1956 Ford V-8	71/83	25.06	3.79	Driving cycles on highway	B	0.264
1956 Ford V-8	64.5/71.5	38.18	1.24	30-min drive on highway	A	0.053
1958 Plymouth V-8	56.5/61.5	32.5	4.74	10 min at 50 mph on dyna	B	0.219
	57/60	31.0	2.38	10 min at 30 mph on dyna	B	0.116
	57/60	30.27	2.31	10 min at 50 mph on dyna	A	0.135
	59/64.5	22.0	1.72	10 min at 30 mph on dyna	A	0.119
	62.5/67.5	25.2	1.21	After 1 hour at idle	A	0.083
	68/76	30.0	3.04	10 min at 50 mph on dyna	A	0.177
	60/69.5	32.0	44.11	Driving cycles on dyna	B	2.213
	57/63	27.75	34.68	Driving cycles on dyna	B	1.988
	62/66	49.0	25.57	Driving cycles on dyna	A	0.810
	64/70	30.0	17.22	Driving cycles on dyna	A	0.964

losses makes it difficult to predict the exact effect of different design changes. However, the great difference noted from one vehicle to another in this study suggests that design studies might be conducted profitably with a view to reducing the amount of carburetor evaporation loss during hot soak periods immediately after shutdown.

Fuel Tank Evaporation Losses

Analytical measurements were made by placing a housing over the fuel tank filler cap, passing air through the housing, and monitoring the air stream continuously with the FIAD as in the measurement of carburetor evaporation losses. Results obtained during several 15-minute driving cycles on the highway displayed more variation than was anticipated. It was suspected that lack of reproducibility was attributable to the aspirating effect of the air flow through the housing, which tended to pull fuel vapors through the vent in the filler cap faster than normal.

To confirm or disaffirm these results, measurements were then made by isolating the tank from the fuel system and determining evaporation losses by weight. The fuel tank was removed from the car, thoroughly cleaned, and filled approximately one-half with fuel. The partially filled tank was weighed and reinstalled in the car; the suction fitting was plugged and the car was then driven from an auxiliary tank during several integrated driving cycles. After sitting overnight the fuel tank was then removed and reweighed.

The results of these measurements (Table IX) appear confusing because the emission rate was higher by the weight method, due evidently to periods of different ambient temperature conducive to breathing of the fuel tank. The effects of sitting overnight prior to reweighing of the tank probably account for the higher emissions by this method. During the nighttime hours, a drop in ambient temperature normally occurs, allowing fresh air to enter the tank through the vent which will in time become saturated with gasoline vapor. Then during an increase in temperature the following morning, the fuel and air in the tank expand, thus forcing air saturated with fuel vapor back out the vent to the atmosphere. In actually applying these results to estimate total daily hydrocarbon emissions, it would appear necessary to establish the relative amount of loss during running as compared to losses which may occur overnight because of the breathing effect.

Conclusions

While results from a much greater number of automobiles would be desirable in order to achieve a higher degree of statistical certainty, the work reported here makes it possible to draw several conclusions concerning various aspects of automotive emissions which were not reported previously, as well as to provide more complete knowledge of certain other aspects.

Based on a numerical average of the vehicles tested, the total hydrocarbon emission during vehicle operation was divided approximately as follows: exhaust, 69%; crankcase blowby, 25%; fuel tank evaporation, 6%; carburetor evaporation, <0.1%.

In view of the limited number of vehicles tested, the ratio between exhaust and crankcase emissions is considered to be in excellent agreement with the values obtained by Rose and Stahman.[2] On the other hand, Bennett, et al.,[3] report larger crankcase emissions in comparison to the amount of exhaust emissions. It is believed that this may be attributed to differences in the sampling and calculation procedures used. In the present investigation, exhaust and crankcase losses were measured over the integrated driving cycle, a procedure that should agree approximately with Rose's procedure of calculating over-all values based on individual measurements at various operating conditions. On the other hand, Bennett relied primarily on cruise samples, and calculated over-all emission rates from these values. As shown in Table V, crankcase emissions appeared to be substantially higher when measured only under cruise conditions, compared to the other results obtained over the integrated driving cycle.

Evaporation losses from the carburetor, while running, constitute less than 0.1% of the total loss, and appear to be of little or no consequence. With the particular vehicles examined, air flow through the various openings in the carburetor appeared to be pri-

Table VIII—Comparison of Fuels by Hot Soak Losses—(1958 Buick V-8, Dynaflow, 2 Bbl Carburetor)

Condition Prior to Hot Soak	Losses, Lb × 10^{-3} Fuel "A"	Fuel "B"
10 min cruising at 50 mph	2.31	4.74
10 min cruising at 30 mph	1.72	2.38

marily from the outside in, thus carrying into the engine any vapor formed by evaporation and minimizing its emission to the atmosphere. With other carburetor designs, this might not always be the case, and measurable evaporation losses during vehicle operation might occur.

Fuel tank evaporation losses constituted approximately six percent of the total loss while operating, which indicates that losses by this route are not of great importance. The variation in results obtained with the two methods of measurement was greater than anticipated, but in spite of this difference the results should indicate the approximate amount of fuel lost in this manner. The possibility of vapor loss while the vehicle was sitting idle, both by diffusion and by "breathing" of the fuel tank, could not be eliminated completely. This means that actual loss during vehicle operation may be somewhat less than the calculated figure of six percent. It is suspected that several variables would affect this loss, including ambient conditions, tank configuration, and fuel volatility. In view of this variability, extrapolation of these results to indicate total daily emissions in a representative city would probably not be valid.

In addition to the data on hydrocarbon losses while running, additional data were obtained to indicate that measurable "hot soak" losses occur by evaporation from the carburetor after shutdown. These losses are relatively independent of the type of carburetor venting, i.e., external or internal vents. The relative amount of vapor lost in this manner would depend on the driving pattern, especially the number of engine shutdowns in an average day and the method of operation immediately prior to shutdown. Other factors which would probably exert some influence on hot soak losses include fuel system design, engine and cooling system condition, ambient conditions, and fuel vapor pressure. An extrapolation of these data to predict total daily carburetor evaporation losses in any typical city would not be valid unless information were available to indicate the effects of these variables.

Table IX—Fuel Tank Evaporation Losses

Operating Period, Hr	Fuel Loss, Lb	Emission Rate, Lb/hr
By Analysis		
0.25	0.0054	0.0216
0.20	0.0048	0.0240
0.21	0.0038	0.0113
0.24	0.0118	0.0492
By Weight Measurement		
2	0.125	0.0625
2	0.125	0.0625
20	2.688	0.1344

Note: All operation was of the integrated cycle type on fuel with a vapor pressure of 8.2 psi Reid. The analytical results were obtained in ambient temperatures in the 90°F plus range. Weight results were obtained during operation in temperatures of 70–80°F with medium solar radiation and cool down periods overnight in temperatures of 60–70°F.

In order to indicate the approximate amount of hot soak loss compared to losses during vehicle operation, the arbitrary assumption of one shutdown and resulting hot soak period per hour of vehicle operation was made. No data on this point were known to be available, and this procedure was chosen arbitrarily as a ratio which would probably be more or less representative of average driving habits in most American cities. On this basis, a numerical average of all determinations indicated that hot soak losses amount to approximately three percent of the total loss during vehicle operation. Individual results varied widely, as discussed previously, and observations made during the tests indicated that the location of the fuel filter and other portions of the fuel system, as well as other design factors, appears to exert a considerable influence on the amount of hydrocarbon vapor lost in this way.

The data provide a comparison of the flame ionization method (FIAD) and nondispersive infrared (IR) measurements. While most of the work was completed with the FIAD, enough runs were completed using both instruments simultaneously to permit some comparison.

From an operational standpoint, better results were obtained with the FIAD. This is probably due to operating difficulties which arose with the particular IR instrument used, since others have reported instruments of this type to be stable and dependable. With the instrument used, trouble was encountered due to zero drift and the extreme vibration sensitivity of the instrument. Therefore, its use was limited to runs made on the dynamometer, where the instrument could be mounted firmly and a stable power source could be provided. For operation in an automobile, a portable 110-volt generator was used as a source of power and the instrument was placed on shock mounts. However, results with this arrangement were unsatisfactory, due primarily to the effects of vibration. The FIAD could be operated satisfactorily in an automobile with this arrangement.

Data obtained simultaneously with both instruments were compared by calculating the ratio FIAD/IR for runs consisting of a complete integrated cycle. Eliminating some runs when a recorder malfunction occurred, ratios for exhaust gas measurements varied from 1.0 to 2.4, with an average of 1.51. The FIAD/IR ratio for road draft tube emissions during the same type of cycle varied from 1.02 to 2.4, with an average of 1.42. In measuring hot soak losses from the carburetor, ratios varied from 0.912 to 1.66, with an average of 1.14.

While an approximate value could be calculated by using a ratio of 1.4 to 1.5, it is evident from these wide ranges that individual runs can vary widely from the average. Therefore, any calculation of one value based on the other type of measurement may be in error by a considerable amount. The reason for these differences is believed to be due to the types of compounds measured by each instrument. The IR, if sensitized with hexane, measures primarily paraffinic hydrocarbons. Most of this measurement takes place by absorption in the 3.4 micron region where C-H bonds are normally measured. Aromatics and oxygenated compounds absorb very weakly in this region, except for higher molecular weight compounds in which portions of the molecule contain paraffinic structures. The FIAD, on the other hand, measures directly the number of carbon atoms present in a mixture. Thus, it is sensitive to aromatics and oxygenated compounds which the IR does not detect, and is equally sensitive to olefins and saturates containing the same number of carbon atoms. Because of this difference in the types of compounds measured, it is believed that a rigorous correlation between the two types of measurement is not possible.

From the standpoint of this project, less variation occurred in measuring the relative contribution of various hydrocarbon sources to the total emission. Based on only a limited number of runs in which both instruments were used simultaneously, it appeared that the relative distribution of losses among the different sources was approximately the same when calculated on the basis of either method of measurement.

Acknowledgment

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REFERENCES

1. *Automotive News*, Almanac Issue, 1959.
2. Andrew H. Rose, Jr., and Ralph C. Stahman, "The Role of Engine Blowby in Air Pollution," *J. Air Poll. Control Assoc.*, 11, 3, 114–117 (March 1961).
3. P. A. Bennett, et al., "Crankcase Gas Causes 40% of Auto Air Pollution," *SAE Journal*, pp. 30–36 (March 1960).
4. Additional data on test conditions will be found in Report No. 32, *Hydrocarbon Emissions from Automobiles*, Air Pollution Foundation, San Marino, California (February 1961).

The ADHESION *of Solid* PARTICLES *to Solid* SURFACES, *I.** A REVIEW

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Dusts and solid aerosols apparently adhere with great tenacity to solid surfaces. Atmospheric dust clings to leaves, walls, fabrics, and automobile surfaces. Inversion of solid surfaces with adhering dust indicates that the gravitational force fails to overcome the adhesion force of most particles. Similarly, vigorous blowing on the surface dislodges only a few particles. Although these observations are commonplace, the quantitative aspects of adhesion of small solid particles to solid surfaces in air are not well defined, and the adhesion mechanism is not well understood.[1] The importance of small particle adhesion in air pollution, air cleaning, and industrial hygiene studies led to this literature review and subsequent research.

Variables which influence the adhesion mechanism are many: investigations devoted specifically to small particle adhesion are few. Efforts which offer significant insight into the adhesion process are often associated with studies not specifically involved with small particle adhesion, and these studies have been liberally drawn upon. This review is organized so as to discuss work on variables thought to be pertinent to small particle adhesion.

Its outline is as follows:

- *A* London-van der Waals Forces
- *B* Effect of Relative Humidity on Adhesion
- *C* Effect of Contact Area on Adhesion
  - *1* Particle shape
  - *2* Particle size
  - *3* Nature of particle and surface material
  - *4* Surface roughness
  - *5* Adhesion of agglomerates vs individual particles
- *D* Effect of Static Electricity on Adhesion
- *E* Effect of Time of Contact on Adhesion
- *F* Effect of Viscous Surface Coating on Adhesion
- *G* Effect of Temperature on Adhesion
- *H* Miscellaneous Adhesion Studies

Interest in adhesion and cohesion between particles and surfaces centered, until recently, on evaluation of London-van der Waals forces in vacuum, or on frictional phenomena between metals. Consideration of these early efforts is advantageous for they focus on variables significantly influencing adhesion phenomena, even if the data are not strictly applicable to micron size particles in air.

London-van der Waals Forces

All molecular and atomic forces ultimately find their root in the mutual behavior of the constituent parts of the atoms, i.e., the nuclei and the electrons, but it is impossible to approach the problem of adhesion from this fundamental basis because too little information is available.[2] The most basic, approximate approach is to calculate adhesion force based on London-van der Waals (dispersion) forces, the forces by which any atom or molecule is attracted by any other atom or molecule, regardless of material composition or physical appearance.

Bradley[3, 4] and Hamaker,[5] starting from the concept of London-van der Waals attraction between molecules, derived equation (1) for the attraction between two spherical macroscopic bodies.

$$F = \frac{\pi^2 q_0^2 \lambda}{12x^2}\left(\frac{d_1 d_2}{d_1 + d_2}\right) \qquad (1)$$

where:

F = attractive force, dynes
x = distance of separation, cm
λ = London-van der Waals constant
q_0 = no. of atoms in one cm³ of the substance
d_1, d_2 = diameters of spherical particles, cm
$\pi^2 q_0^2 \lambda = 10^{-12}$ as given by Hamaker[5]

Bradley[3] confirmed equation (1) with relatively large, freshly fused quartz and sodium pyroborate spheres in vacuum, obtaining equations (2 and 3).

or Quartz:

$$F = 212\left(\frac{d_1 d_2}{d_1 + d_2}\right) \text{ dynes}$$

$$\left(0.2 \text{ mm} \leq \frac{d_1 d_2}{d_1 + d_2} \leq 0.6 \text{ mm}\right) \qquad (2)$$

for $Na_2B_4O_7$:

$$F = 434\left(\frac{d_1 d_2}{d_1 + d_2}\right) \text{ dynes}$$

$$\left(0.5 \text{ mm} \leq \frac{d_1 d_2}{d_1 + d_2} \leq 1.7 \text{ mm}\right) \qquad (3)$$

The same results were reported for measurements in dry air and vacuum.

Prior to the efforts of Bradley and Hamaker, Tomlinson[6, 7] and Stone[8] reported contradictory results on the cohesion of solids. Freshly fused glass beads of one or two millimeter diameter were used by both investigators in conjunction with microbalance techniques. Stone reported negligible, barely detectable adhesion in dry air with increased adhesion in the presence of water vapor. Different types of glass exhibited various degrees of adhesion, with Jena glass adhering strongly, presumably due to static electrification. Adhesion was attributed to water vapor for all other beads. Tomlinson reported erratic behavior of glass beads and therefore concentrated on quartz beads. Observed cohesion of quartz beads and quartz fibers was high in a dry, dust free atmosphere and was attributed to true cohesion between molecules of adjoining surfaces, and not to water vapor.

If the diameter of one sphere in equation (1) is allowed to approach infinity, equation (4) for the case of a

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sphere adhering to a flat plate is obtained. The symbols have the same significance as above.

$$F = \frac{\pi^2 q_0^2 \lambda d_1}{12x^2} = \frac{A d_1}{12x^2} \qquad (4)$$

Utilization of equation (4) is limited in practice. One must assume values for x, the distance of separation, and $\pi^2 q_0^2 \lambda$, or A, which varies from 10^{-11} to 10^{-13} ergs for various materials. This constant has been the subject of extensive research[3, 9–13] and its value is still not firmly established. In the absence of electrostatic charge in a highly evacuated system with molecularly smooth surfaces, the adhesive force between particle and surface would be attributable to London-van der Waals forces between molecules of the solid. Under conditions of interest to industrial hygiene and air pollution, i.e., particles in air or in industrial effluents, the presence of adsorbed gases or condensed moisture on the solid surfaces, as well as surface roughness, would probably result in London-van der Waals forces between the solids having little influence on any observed adhesion. The forces are negligible beyond two molecular distances, or approximately 10 Angstroms.[2, 14]

One investigation, that of Tunitskii and Petryanov,[49] indicated a greater range of effectiveness of van der Waals forces. They examined aerosol particles near a solid wall and found the percentage of particles adhering to the wall higher than would be expected in the absence of molecular attraction between particle and wall. Depending on stream velocity the effective particle radius was concluded to be up to 80% greater than the geometric radius, and van der Waals attraction was significant at distances equal to particle radii. Their equations are subject to the same limitations mentioned in conjunction with equation (4).

Effect of Relative Humidity on Adhesion

Bowden and Young[15] found that . . . "if surface layers are removed so that intimate contact occurs between the atoms of the two metal surfaces, we may expect the strength of the junction to approach that of the bulk metal." As soon as clean surfaces were allowed to touch each other, "complete seizure occurred even at room temperature."

Bowden, Young, and Rowe[16] confirmed the increase of friction when metallic surface films are removed. They noted that admission of a small amount of oxygen, water vapor, or other contaminant reduces this friction.

Stone[8] and Budgett[17] indicated adhesion above a small, negligible value barely detectable with a microbalance (10^{-6} g sensitivity) was due to water vapor. Bowden and Tabor[18] cite work by McFarlane and Tabor[19] on the forces of adhesion due to a small amount of liquid interposed between a glass sphere and a glass plane. For glass spheres from 133 to 500 micron diameter, equation (5) was very closely followed.

$$F = 2\pi\gamma D_p \qquad (5)$$

where:

- F = perpendicular force of adhesion, dynes
- γ = surface tension of liquid, dynes/cm
- D_p = sphere diameter, cm

Equation (5) has been derived by Derjaguin,[20] Bradley,[3] Bowden and Tabor,[18] and Larsen,[21, 22] as the maximum possible adhesion between a perfectly smooth sphere and solid surface in a saturated atmosphere.

McFarlane and Tabor[23] in more recent work found equation (6) applicable to the calculation of the force of adhesion between a sphere and a flat plate with an interposed water film.

$$F = 4\pi\gamma R \qquad (6)$$

where:

- F = perpendicular force of adhesion, dynes
- γ = surface tension of water, dynes/cm
- R = radius of water film surrounding lower part of sphere, cm

Variation in adhesion for an unspecified glass sphere and plate is shown in Fig. 1.

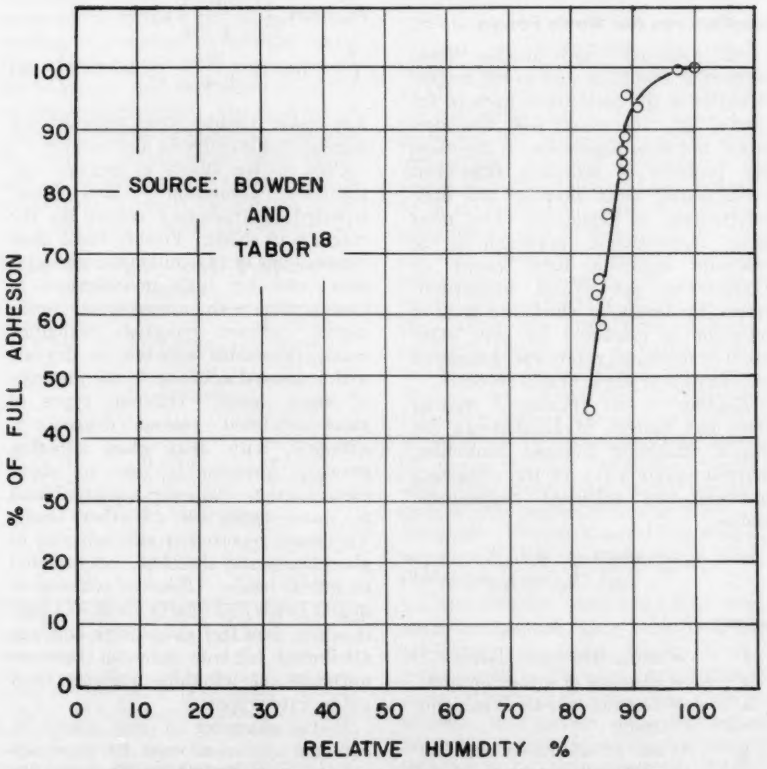

Fig. 1. Adhesion of glass spheres to glass slides as f (relative humidity).

Kordecki, Gladden, and Orr[24] indicate the applicability of equation (6) and describe a geometrical system for calculating R based on film thickness. These authors believe film thickness can actually submerge small particles. However, Harkins[25] indicates mean film thickness of water on quartz (SiO_2) of approximately 15 Angstroms, or three molecular layers at saturation. Film thicknesses of 15 Angstroms do not explain the large adhesions observed, unless condensation occurs at the sphere—solid contact. Bowden and Throssel[26] report water vapor adsorption of less than two molecular layers on gold, platinum, silver, and aluminum at relative pressures below saturation, but indicate that a small amount of hygroscopic surface material could explain literature reports of large adsorption of water on solids.

Larsen[21] did not systematically study the effect of relative humidity on the adhesion of particles to fibers, but observed that at 40% relative humidity one inch of water velocity head was required to blow spherical glass particles off fibers as compared to similar results with 0.1 inch water velocity head at 22% relative humidity.

Table I—Contact Area of Different Geometrical Shapes[24]

Geometric Shape of Particle	Area of Face, of the Figure, Cm^2
Tetrahedron	1.163×10^{-8}
Cube	1.650×10^{-8}
Octahedron	0.464×10^{-8}
Dodecahedron	0.278×10^{-8}
Icosahedron	0.166×10^{-8}
Sphere	0.000×10^{-8}

Kordecki and Orr[27] present results for adhesion of particles of many materials to solid surfaces, but variation in adhesion with relative humidity was not consistent. Thus, for sand on an enamel surface adhesion was stronger at 10% rh than at 50% rh, while for unspecified glass on glass adhesion increased with relative humidity. Other uncontrolled variables in their experiment, such as surface roughness and static electrification, could explain these results.

It is obvious from the above discussion that relative humidity of the ambient air should greatly influence the adhesion of solid particles to solid surfaces, but the nature of the influence is not clear.

Effect of Contact Area on Adhesion

Influence of Particle Shape

Kordecki, Gladden, and Orr[24] present Table I as illustrative of the effect of particle shape on adhesion. The sphere and each of the regular polyhedra are assumed to be perfectly smooth and to contain 1.5708×10^{-12} grams of material with a density of 3.0 g/cm^3.

Influence of Particle Size

Equations given above, as well as the work of Larsen[21, 22] and Kordecki and Orr[27] indicate that adhesion forces increase with particle size. However, the two latter studies employed centrifugal force or air jets to effect particle removal, mechanisms dependent on the cube and square of particle diameter, respectively. Therefore, larger particles were easier to remove, in general, than smaller particles retained on the surface by lower adhesion forces.

Table II—Adhesion Data for Various Materials[26]

Identification of Materials		Force Required to Remove 98% of 50μ Diam Particles at Various Humidities		
Particle	Solid Surface	90%, Dynes	50%, Dynes	10%, Dynes
Glass	Aluminum	0.50	1.35	1.06
	Glass	1.83	0.37	0.15
	Plexiglass	1.97	1.44	
Sand	Aluminum	6.60		
	Glass	0.06	0.74	1.21
Charcoal	Aluminum	0.97		
	Glass	0.94	0.55	1.19
	Plexiglass	0.70		
Rubber	Glass	0.81		
	Plexiglass	1.93		

Nature of Particle and Surface Material

Kordecki and Orr[27] and Cremer, Conrad, and Kraus[28] present adhesion data for various materials. The latter investigators were interested in using a tilting plate and variation in adhesion with particle size as a separatory mechanism for dolomite and magnetite ores. Adhesion varied with the material and surface employed. Data of Kordecki and Orr[27] are shown in Table II, which indicates the dependence of adhesion on particle material, as well as on particle shape, for this variable was not specified.

Influence of Surface Roughness

Bowden and Tabor[18] and Larsen[21] evaluated the effect of surface roughness on adhesion. Table III presents the findings of Bowden and Tabor, which indicates decreased adhesion with increased surface roughness. Larsen concluded that adhesion increases with surface roughness, a result now believed to be due to the presence of electrostatic charge in his experiments.

Increasing surface roughness decreases the real area of contact between solid surfaces. All surfaces, even highly polished ones, are composed of surface asperites and valleys.[29–31] Under load, the asperites deform plastically. Figure 2 indicates that under very light loads, the real area of contact between steel plates can be as little as 0.00001 of the apparent contact area. Bowden[30] calls attention to the close connection between adhesion and friction. Friction is essentially the shear strength and adhesion the tensile strength of junctions formed at the region of contact. Rayleigh[32] during a study of the cohesion of glass surfaces, noted that except for isolated contact of surface asperites, highly polished silica surfaces remained separated by an average distance of 24.7 Angstroms. Pascoe and Tabor[33] studied the friction of polymers in vacuum and concluded that circular fibers contact at one, or at most a few surface asperites under loads of 0.1 g or less. Frictional properties of the fibers were attributed to deformation of these isolated contacts.

In summary, the role of surface roughness in adhesion is very poorly defined. In the case of small particles in air, there is reason to believe that the adsorbed surface film is not penetrated. If the film is ruptured by particle impaction, contact is at one, or at most a few surface asperites. Measurement of surface roughness is impractical and this variable will, in all field work, remain unknown.

Influence of Agglomerates

Forces of adhesion between a surface and an agglomerate are probably different from the forces of adhesion between the surface and individual particles of the same material. An agglomerate will contact the surface differently than an individual particle of the same apparent size. In terms of ease of particle removal from the surface, one can only note that the apparent density of an agglomerate can differ by an order of magnitude from that of the particle material if the agglomerate is composed of heterogeneous particles.[34]

Effect of Static Electricity on Adhesion

The precise mechanisms by means of which static electric charge is produced on solid surfaces is not completely understood. Anderson[35] presents an excellent review on the present state of knowledge. Kunkel[36] studied the charge and size distribution of particles from 0.5 to 30 microns radius in dust clouds of quartz, sulfur, and carbohydrates under a variety of conditions. All dusts studied were charged. In general, static electrification of a solid in air is humidity dependent, with higher charge buildup at low relative humidities;[35] however, some plastics have been shown to hold charge at 100% relative humidity.[37] While there is abundant evidence that particle and surface will hold charge before contact, the distribution of charge after contact, and its effect on adhesion is not clear.

Gaines and Tabor[38] and Gaines[39] suggest that the adhesive force between mica surfaces is ionic in nature. They present evidence on the ion transfer of Potassium-42 after contacting mica surfaces. Water reduces mica-to-mica adhesion and this is attributed to the high dielectric constant and the occurrence of hydrogen

Table III—Adhesion of Glass Spheres to Glass Plate in Atmosphere of 100% Relative Humidity[18]

Surface Finish	Mean Approximate Height of Surface Irregularities, Angstroms	Adhesion as Percent of Value Observed with Highly Polished Surfaces
Highly polished	150	100
500 carborundum paper	1,000	79
320 carborundum paper	4,000	51
150 carborundum paper	100,000	0

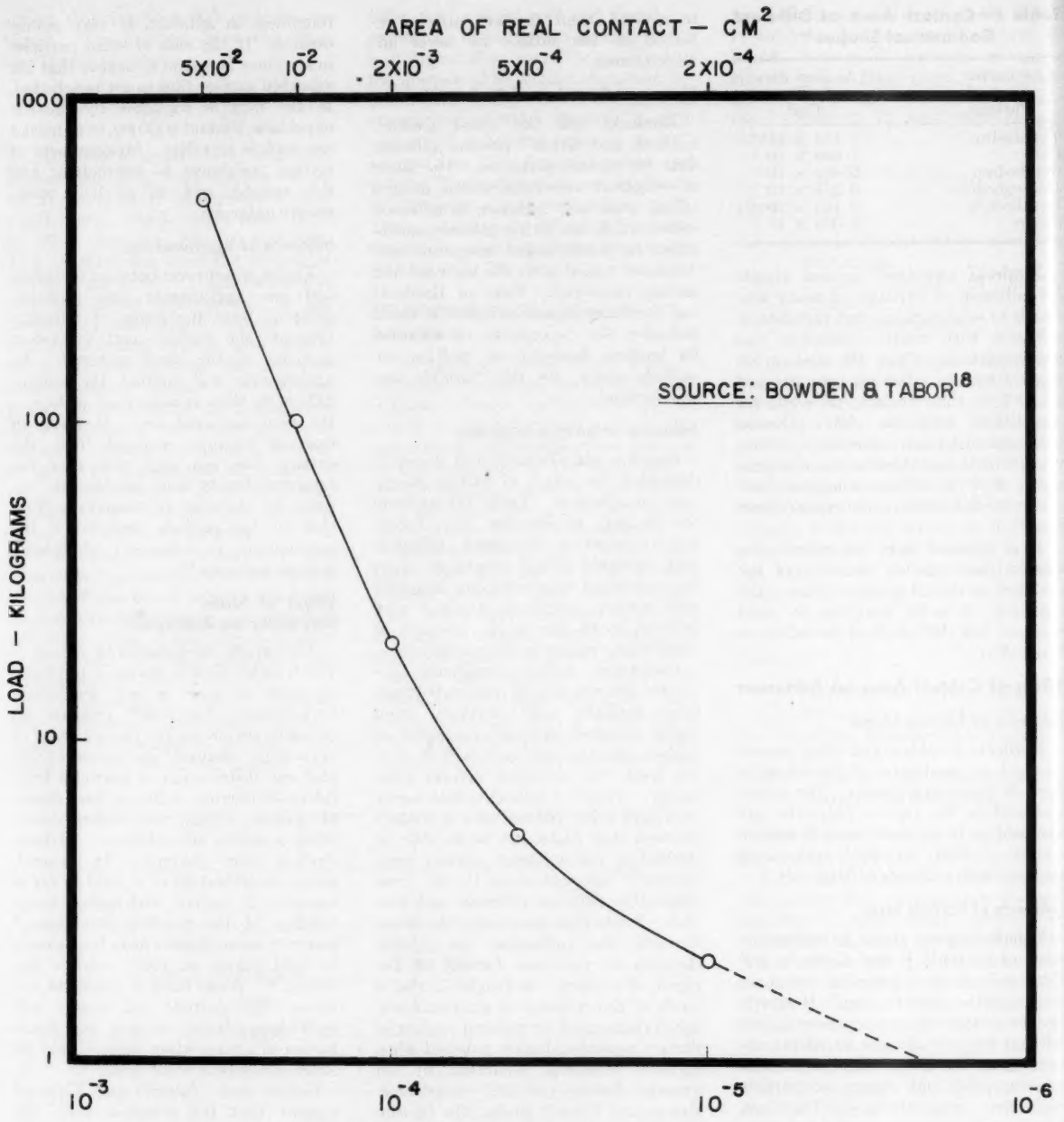

Fig. 2. Area of real contact vs load for steel flats (21 cm² area).

ion-potassium ion exchange contributing to the reduction of attraction. Young[40] postulates a similar ionic mechanism for water adsorption on silica.

Effect of Time of Contact on Adhesion

Work is not reported in the literature on this aspect of small particle adhesion. For a steel ball 0.125 inch in diameter on an indium block with 500 g load, Bowden and Tabor[41] report full adhesion was reached in 2000 seconds. It is difficult to extrapolate these data to micron size particles where essentially no load is applied.

Effect of Viscous Surface Coatings on Adhesion

Larsen[21, 22] found equation (7) described air jet removal of glass spheres from oil coated fibers. This equation predicts enormous forces of adhesion

$$\frac{A_w}{A_f} = \frac{1330\mu}{D_p H^{1.5}} \qquad (7)$$

where:

A_w = cross sectional area of particles and oil in fiber wake
A_f = cross sectional area of fiber
D_p = particle diameter, microns
H = air flow velocity head, inches H_2O
μ = oil viscosity, poises

Effect of Temperature on Adhesion

Variation in adhesion between solid particles and solid surfaces as a function of temperature is not reported in the literature. However, if an adsorbed water film influences adhesion, as described above, surface tension varia-

tion of the adsorbed film can be used to estimate adhesion variation with temperature.

The surface tension of all liquids decreases as the temperature is increased and becomes zero at the critical temperature. The temperature dependence of surface tension is successfully represented for many liquids by the Ramsay-Shields Equation.[42] Water has a surface tension of 72.75 dynes/cm at 20°C and 62.61 dynes/cm at 80°C.

Miscellaneous Adhesion Studies

Beischer[43] employed an ingenious technique to study the breaking strength of threadlike particle aggregates of ammonium chloride, anthracene, and iron oxide composed of particles 0.1–1.0 micron diameter in size. As the aggregate chain grew by condensation, its weight and diameter were monitored by microbalance and microscope. The aggregate weight caused its own rupture. In the absence of electrostatic or magnetic forces, breaking strengths of 50–500 g/cm² were observed. Iron oxide breaking strengths of 10–40 kg/cm² were attributed to magnetic dipoles of the particles.

Jordan[44] deposited quartz and glass dust on glass slides, sized the deposits, then directed air jets at the slides and noted particle removal at various jet velocities (Fig. 3). Material nature and ambient air conditions were not reported.

Lowe and Lucas[45] assumed the forces holding particles to surfaces are molecular in nature, and of the same order as the bulk strength of the material within an effective distance of 10^{-8} cm. They arrived at equation (8) for the adhesion between two spheres of diameters d_1 and d_2 and tensile strength U.

$$F = \pi U \left(\frac{d_1 d_2}{d_1 + d_2}\right) \times 10^{-8} \text{ cgs units} \qquad (8)$$

Latty and Clark[46] collected samples on a Formvar coated electron microscope grid from a titanium oxide cloud of particles from 0.2–2 micron diameter. From electron micrographs the maximum chain length of aggregates was determined and the force between particles calculated in a manner analogous to that used by Beischer.[43] The adhesion was greater than, or equal to, 6×10^{-7} dyne.

Buzagh[47, 48] allowed two to three micron quartz particles from a poly-disperse water suspension to settle on a tiltable glass plate. By inclining or inverting the plate adhesion forces could be calculated from particle mass. The settled particles on the plate were observed to be in vivid random motion, due, presumably, to a buffer water film between particle and surface. Buzagh estimated the adhesion force for spherical particles to be 0.3 dyne/cm², which is lower than adhesion observed in air by many investigators.

Conclusions and Summary

The above review leads to the following conclusions.

The theory of London-van der Waals molecular forces cannot be successfully extended to quantitatively predict adhesion forces of small particles in air where adsorbed gases prevent close approach of solid surfaces.

Ambient air relative humidity influences adhesion, but the nature of this influence is not clear, due to contradictory reports in the literature.

The real area of contact between particles or particle and surface differs from the apparent contact area. It may be altered by particle shape, particle and surface roughness, and extent of particle agglomeration. Particle size also influences contact area and adhesion has been repeatedly observed to increase with particle size.

Static electrification of particle and surface may alter forces of adhesion, but data are not reported.

Ambient air temperature and time of particle-surface contact have not been studied for their influence on small particle adhesion in air.

Few studies have been specifically devoted to adhesion of micron size particles in air, and these have not attempted to systematically study variables which may alter the mechanism. These studies indicate that variables treated here, and possibly others, act together to yield forces of adhesion which differ for each particle-surface combination.

In summary, there is need to clarify the mechanism of small particle adhesion in air. It is intrinsic to aerosol sampling, dust filtration, dust reentrainment, and soiling phenomena. This review was undertaken to survey efforts to date and to focus future research.

REFERENCES

1. N. A. Fuchs, "The Mechanics of Aerosols," CWL Spec. Pub. 4-12, USWCL, Army Chemical Center, Maryland, 412 (1955). Trans. by E. Lachowicz.
2. F. O. Rice and E. Teller, *The Structrue of Matter*, John Wiley & Sons, Inc., New York, 23 (1949).
3. R. S. Bradley, "The Cohesive Force between Solid Surfaces and the Surface Energy of Solids," *Phil. Mag.*, **13**: 853 (1932).
4. R. S. Bradley, "The Cohesion between Smoke Particles," *Trans. Far. Soc.*, **32**: 1088 (1936).
5. H. C. Hamaker, "The London-van der Waals Forces between Spherical Particles," *Physica*, **4**: 1058 (1937).
6. G. A. Tomlinson, "Molecular Cohesion," *Phil. Mag.*, **6**: 695 (1928).
7. G. A. Tomlinson, "Further Experiments on the Adhesion of Quartz Fibers," *Phil. Mag.*, **10**: 541 (1930).
8. W. Stone, "Some Phenomena of the Contact of Solids," *Phil. Mag.*, **9**: 610 (1930).
9. A. E. Bailey and J. S. Courtney-Pratt, "The Area of Real Contact and the Shear Strength of Monomolecular Layers of a Boundary Lubricant," *Proc. Roy. Soc.*, **227**: 500 (1955).
10. J. Th. G. Overbeek and M. Sparnaay, "London-van der Waals Attraction between Macroscopic Objects," *Disc. Far. Soc.* **18**: 12 (1954).
11. B. Derjaguin, "Investigations of the Forces of Interaction of Surfaces in Different Media and Their Application

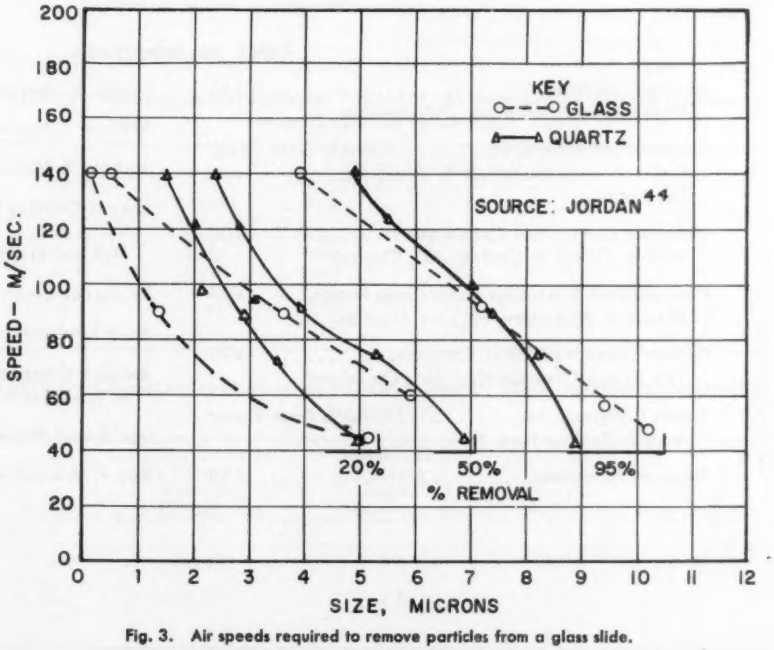

Fig. 3. Air speeds required to remove particles from a glass slide.

to the Problem of Colloidal Stability," *Disc. Far. Soc.*, **18**: 24 (1954).
12. B. Derjaguin, I. I. Abriksova, and E. M. Lifshitz, "Direct Measurement of Molecular Attraction between Solids Separated by a Narrow Gap," *Quart. Rev. Chem. Soc.*, **10**: 295 (1956).
13. A. P. Prosser and J. A. Kitchner, "Direct Measurement of Long Range van der Waals Forces," *Nature*, **178**: 1339 (1956).
14. H. J. Lowe and D. H. Lucas, "The Physics of Electrostatic Precipitation," *Brit. J. Appl. Phys.*, **3**: S40 (1953).
15. F. P. Bowden and J. E. Young, "Friction of Clean Metals and the Influence of Adsorbed Films," *Proc. Roy. Soc.*, **A208**: 311 (1951).
16. F. P. Bowden, J. E. Young, and G. Rowe, "Friction of Diamond Graphite and Carbon; The Influence of Adsorbed Films," *Proc. Roy. Soc*, **A212**: 444 (1951).
17. H. M. Budgett, "The Adherence of Flat Surfaces," *Proc. Roy. Soc.*, **A86**: 25 (1911).
18. F. P. Bowden and D. Tabor, "The Friction and Lubrication of Solids," Clarendon Press, Oxford, **302** (1950).
19. J. S. McFarlane and D. Tabor, VII Int. Congress for Appl. Mech., **V.IV**, London, 31 (1948).
20. B. Derjaguin, "Untersuchungen Uber die Reibung und Adhasion," *Koll. Zeit.*, **69**: 155 (1934).
21. R. I. Larsen, "Ph.D. Thesis," Harvard University (October 1957).
22. R. I. Larsen, "The Adhesion and Removal of Particles Attached to Air Filter Surfaces," *Am. Indust. Hyg. A. J.*, **19**: 265 (1958).
23. J. S. McFarlane and D. Tabor, "Adhesion of Solids and the Effect of Surface Films," *Proc. Roy. Soc.*, **A202**: 224 (1950).
24. M. C. Kordecki, J. K. Gladden, and C. Orr, "Adhesion between Solid Particles and Solid Surfaces," Final Report Project B-148, Eng. Expt. Sta., Georgia Inst. Tech., Atlanta (September 1959).
25. W. D. Harkins, "The Physical Chemistry of Surface Films," Reinhold Publishing Company, New York, 243 (1952).
26. F. P. Bowden and W. R. Throssel, "Adsorption of Water Vapor on Solid Surfaces," *Proc. Roy. Soc.*, **A209**: 297 (1951).
27. M. C. Kordecki and C. Orr, "Adhesion of Solid Particles to Solid Surfaces," *A.M.A. Arch. Env. Hlth.*, **1**: 1 (1960).
28. E. Cremer, F. Conrad, and T. Kraus, Die haftfahigheit of pulvern und ihre anwendung zu bestimmung von Kron grossen," *Angew. Chem.*, **64**: 10 (1952).
29. J. I. Bikerman, "Surface Chemistry for Industrial Research," Academic Press, New York, 167 (1948).
30. F. P. Bowden and D. Tabor, "Mechanisms of Adhesion between Solids," Proc. 2nd Int. Congress on Surface Activity, Butterworth Scientific Pub., London, 386 (1957).
31. D. Tabor, "Junction Growth in Metallic Friction: The Role of Combined Stresses and Surface Contamination," *Proc. Roy. Soc.*, **A251**: 378 (1959).
32. Lord Rayleigh, "A Study of Glass Surfaces in Optical Contact," *Proc. Roy. Soc.*, **A156**: 326 (1936).
33. M. W. Pascoe and D. Tabor, "Mechanisms of Adhesion between Solids," *Proc. Roy. Soc.*, **235**: 210 (1956).
34. H. F. Johnstone, "The Agglomeration of Solid Aerosol Particles," Tech. Rpt. No. 16, Eng. Expt. Sta. Univ. Ill., Urbana (March 1959).
35. D. M. Anderson, Ph.D. Thesis, Harvard University (1958).
36. W. B. Kunkel, "The Static Electrification of Dust Particles on Dispersion into a Cloud," *J. Appl. Phys.*, **21**: 820 (1950).
37. P. C. Woodland and E. E. Zeigler, "Static Electrification of Plastics," Dow Chemical Co., Midland, Michigan (1951).
38. L. G. Gaines and D. Tabor, "Surface Adhesion and Elastic Properties of Mica," *Nature*, **178**: 1304 (1956).
39. L. G. Gaines, "Adhesion and Ion Exchange between Mica Surfaces," *Nature*, **183**: 1109 (1959).
40. G. J. Young, "Interaction of Water Vapor with Silica Surfaces," *J. Coll. Sci.*, **13**: 67 (1958).
41. F. P. Bowden and D. Tabor, "The Friction and Lubrication of Solids," *op. cit.*, 307.
42. C. F. Prutton and S. H. Maron, "Fundamentals of Physical Chemistry," Rev. Ed., MacMillan Co., New York, 240 (1951).
43. V. D. Beischer, "Festigkeitsuntersuchungen an aerosolsedimenten," *Koll. Zeit.*, **89**: 214 (1939).
44. D. W. Jordan, "The Adhesion of Dust Particles," *Brit. J. Appl. Phys.*, **3**: S194 (1954).
45. H. J. Lowe and D. H. Lucas, "The Physics of Electrostatic Precipitation," *Brit. J. Appl. Physics* **3**: S40 (1953).
46. J. E. Latty and W. C. Clark, "Forces between Titanium Oxide Pigment Particles," *Nature*, **184**: 49 (1959).
47. A. Buzagh, "Uber die haftfahigkeit mikroskopischer teilchen an wanden von gleicher beshaffenheit," *Koll. Zeit.*, **51**: 105 (1930).
48. A. Buzagh, "Uber die haftfahigkeit und raumerfullung mikroscopischer teilchen," *Kolloidchem. Beih.*, **32**: 114 (1931).
49. V. N. Tunitskii and I. V. Petrayanov, "On the Theory of Aerosol Filtration, I.: The Role of van der Waals Forces," *Zhur. Fiz. Chem.*, **17**: 408 (1943). Trans. by E. R. Hope.
50. F. P. Bowden, "Adhesion and Friction," *Endeavor*, **16**: 5 (1957).

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The Radial DISTRIBUTION *of* SULFUR DIOXIDE SOURCE STRENGTH *and* CONCENTRATION *in Nashville**

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The U. S. Public Health Service Division of Air Pollution and the School of Medicine of Vanderbilt University conducted a study[1, 2] in Nashville, Tennessee, in 1958–1959 to investigate possible relationships between air pollution and health and to obtain information on a number of the engineering and meteorologic phases of air pollution. As one aspect of the study, sulfur dioxide was studied intensely, from a detailed emission inventory to ambient air measurements using several sampling techniques. This paper discusses sulfur dioxide source strength and ambient levels of sulfur dioxide reported in terms of sulfation, using lead peroxide candles, as a function of radial distance from the center of Nashville.

Source Study

A sulfur dioxide emission inventory for each of 324 one mile squares of Nashville and the immediate vicinity was based on tabulations of the size, nature, and location of sources; industrial and domestic fuel-use data; engineering estimates of emissions from sizeable industrial sources; meteorologic information (especially degree-day data); questionnaires completed by industrial plants; and emission rates from the literature.

Coal combustion was the most important source of sulfur dioxide. Considerable amounts of coal are used by commercial and industrial plants and 35% of domestic heating is derived from bituminous coal.

For the purposes of this study, Nashville was divided into concentric rings and the median sulfur dioxide source strength for each ring for the year and each season (September to November, December to February, etc.) was plotted (Fig. 1). Both emission and sulfation appeared uniformly high near the center of town, dropped rapidly toward the city edge, and slowly decreased into the suburban and rural areas. The general shape of the curve suggested a typical bell-shaped Gaussian or "normal" curve and test plots verified this. Sulfation data appeared to fit quite well and emission data, fairly well.

The "normal" equation may be expressed as follows:

$$y = \frac{e^{-1/2(x/s)^2}}{\sqrt{2\pi}} \qquad (1)$$

where:

- y = frequency of occurrence
- e = transcendental number 2.718
- x = value of the variable, measured from the mean
- s = standard deviation of the variable.

Equation 1 may be changed slightly to express the radial distribution of sulfur dioxide emission in Nashville as follows:

$$E = E_c e^{-1/2\left(\frac{r}{s_r}\right)^2} \qquad (2)$$

where:

- E = emission strength
- E_c = emission strength at the center of Nashville
- r = radial distance from the center of Nashville
- s_r = a new term, analogous to standard deviation, and called standard radial deviation.

Median emission values for several radial distances for each season (fall 1958 through summer 1959) and the year were determined (Table I) and plotted (Fig. 1). The annual, fall, and spring values appear to be comparable. The summer emission rate in the center of Nashville is approximately one-

Table I—Median Sulfur Dioxide Emission, by Season, vs Radial Distance from Center of Nashville

Radial distance, miles	Emission, lb SO_2/mi²/day				
	Annual	Fall	Winter	Spring	Summer
0.4	8000	5900	20,000	6500	750
1.2	4100	3000	10,000	3300	420
2.0	1900	1400	4,800	1500	90
2.8	590	440	1,500	500	20
3.6	370	270	860	340	0
4.4	160	110	390	130	0

Table II—Characteristics of Radial Distribution of SO_2 Emission in Nashville by Season

Season (1)	E_c, SO_2 Emission in Center of Nashville, lb SO_2/mi²/day (2)	Sulfation Ratio at Center of Nashville, Season/Annual (3)	S_r Standard Radial Deviation, Miles (4)	S_r/ Nashville Radius (5)
Winter	19,000	2.9	1.2	0.27
Fall, Spring, Annual	6,500	1.0	1.2	0.27
Summer	800	0.12	1.2	0.27

* Presented at the 54th Annual Meeting of APCA, Commodore Hotel, June, 11–15, 1961, New York, New York.

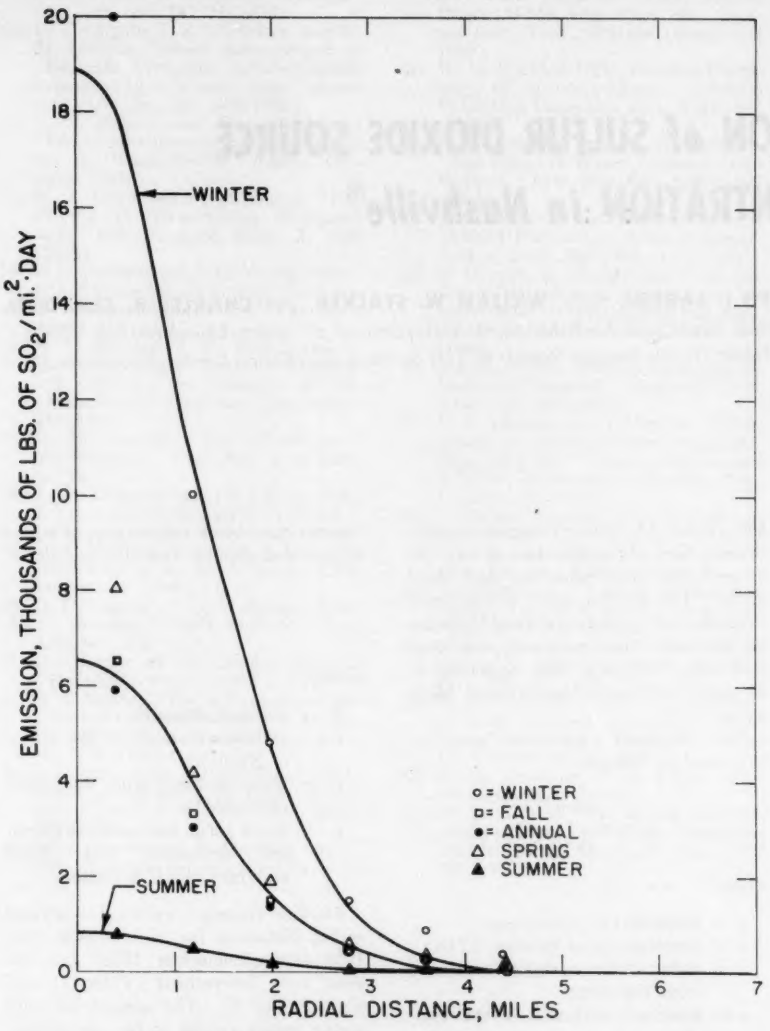

Fig. 1. Median SO_2 Emission by season vs radial distance from center of Nashville.

eighth as great as the annual average; the winter rate is three times the annual average (Table II, column 3).

Visual lines of best fit were constructed through the three sets of points on Fig. 1. The cumulative area under each of the three curves was then plotted as a function of radial distance on arithmetic probability paper (Fig. 2). For a normal frequency distribution, one standard deviation is the variation from the mean at the point where 84% of the area under the curve occurs. Similarly, the standard radial deviation is defined as the radial distance from the center of town, where 84% of the area under the curve (only half of which is shown in Fig. 1) occurs. For each of the seasons and for the entire year, a value of approximately 1.2 miles for the standard radial deviation seems to fit best. This value was substituted in equation 2 and the theoretical curves were then drawn on Fig. 1 as shown.

Thus the median emission at a given radial distance from the center of Nashville may be approximated using only two parameters, E_c, the emission at the center of Nashville, and s_r, the standard radial deviation. Since the built up area of Nashville (a city of 167,000 population) is approximately 4.5 miles in radius, the standard radial deviation of 1.2 miles is approximately one-fourth the radius of Nashville (Table II).

Table III—Characteristics of Radial Distribution of Sulfation in Nashville by Season

	Sulfation, μgm SO_3/cm²/day		Sulfation Ratios		S_r Standard Radial Deviation, Miles	S_r/ Nashville Radius	
	$S_b + S_c$ Center of Nashville	S_b Background	Center/ Background	Season/ Annual		Calculated	Rounded
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Winter	16.9	2.5	6.8	3.0	1.7	0.38	0.4
Fall, Spring, Annual	5.7	1.0	5.7	1.0	1.35	0.30	0.3
Summer	1.5	0.2	7.5	0.26	1.0	0.22	0.2

Sulfation

One lead peroxide cylinder was located at each of the 119 urban and four control sampling stations (Fig. 3). Samples were changed monthly. Basically the lead peroxide sampler, which is housed in a protective shelter 11 feet above the ground (Fig. 4), consists of an eight-ounce glass cylindrical jar around which is wrapped a gauze coated with a paste containing lead peroxide. The sampler measures the sulfation rate of the ambient atmosphere. The amount of sulfation was determined by a Tennessee Valley Authority modification of the standard gravimetric sulfate method[3-5] which was developed in 1932 by Wilson and McConnell.[6] The relationship between lead peroxide sulfation rates and sulfur dioxide mean levels has been reported by others[5, 7] to be approximately 2.5 ppb for 1 μgm SO_3/cm²/day.

The sampling station network (Fig. 3) may be considered as a series of concentric hexagons radiating from the central station (60). The average radius for each hexagon was determined. The geometric mean sulfation for all the stations in each ring for each season was then determined and plotted (Fig. 5). The points appear to fit the bell-shaped "normal" curve, except that sulfation does not decrease to zero, but rather to a background level. Thus equation 2 may be altered slightly as follows:

$$S = S_b + S_c e^{-1/2\left(\frac{r}{s_r}\right)^2} \qquad (3)$$

where:

S = sulfation
S_b = the background sulfation
S_c = sulfation at the center of Nashville (minus S_b).

As with source strength, the fall, spring, and annual sulfation values appeared comparable[2] and were plotted as one curve. Also similar to source strength, sulfation at the center of Nashville was three times as great in winter as for the year (Table III, column 5). The summer sulfation was

about one-fourth the annual value, however, as compared with one-eighth for source strength.

Standard radial deviation for sulfation was determined in a manner similar to that for emission (Fig. 6). In this case, however, area under the curve but above the background level was determined. The standard radial deviation was approximately 0.2, 0.3, and 0.4 times the radius of Nashville for summer, fall-spring-annual, and winter, respectively (Table III). Sulfation in the center of Nashville was approximately seven times as great as background sulfation for each season (Table III).

Equation 3 gives median sulfation as a function of radial distance. Results from many of the 123 stations would still be required to detect local differences, such as the elevated concentration in western Nashville near station Nos. 4 and 10 (Fig. 7).

Relating Emission to Sulfation

The emission and sulfation values (from equations 2 and 3) for each season have been plotted for several radial distances (Fig. 8). The data tend to fit a straight line when plotted on logarithmic paper, indicating that the results may be expressed as follows:

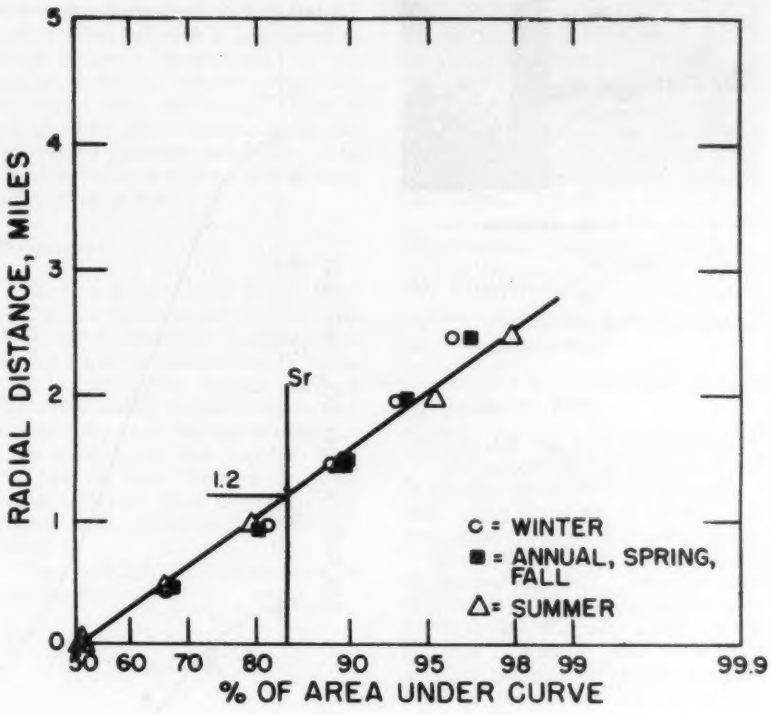

Fig. 2. Area under Fig. 1 emission curve.

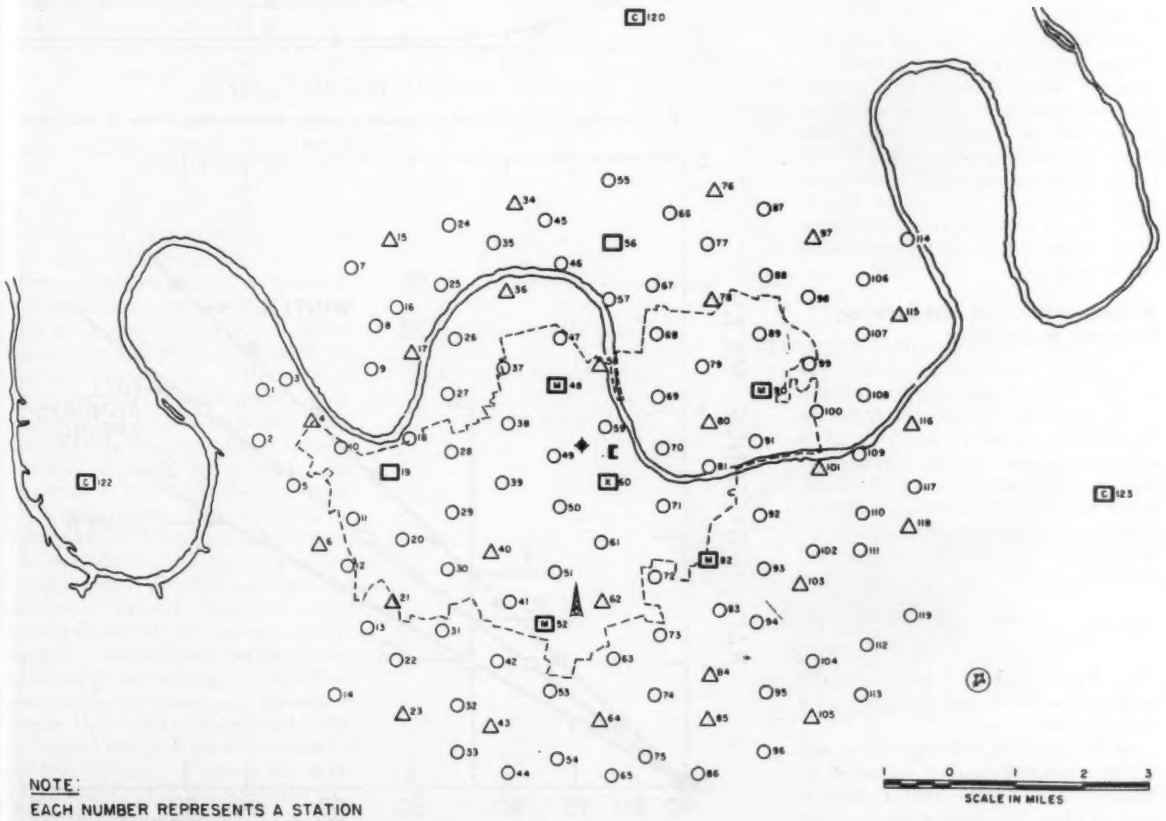

Fig. 3. Nashville community air pollution study. Aerometric station network.

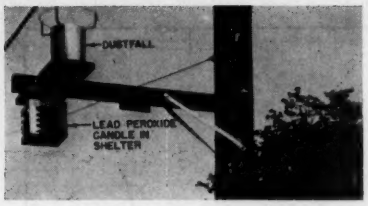

Fig. 4. Aerometric station.

winter, sulfation =
$$0.13\ (\text{emission})^{0.5} \quad (4)$$

annual-fall-spring, sulfation =
$$0.06\ (\text{emission})^{0.5} \quad (5)$$

summer, sulfation =
$$0.002\ (\text{emission}) \quad (6)$$

where sulfation is in μgm SO_3/cm^2/day and emission is in lb of SO_2/mi^2/day.

These equations relate the emission to the sulfation at the same point. Sulfation decreases more slowly than emission as points further from the center of town are taken. Thus sulfation may be expressed as proportional to emission to the 0.5 power (for each season except summer). The sustained sulfation values are due to the fact that sulfation at a point is affected not only by emission at that point, but also by the higher emissions near the center of town. The mathematical model to follow will evaluate these effects in greater detail.

The significance of the low emission-low concentration summer values, indicating a linear relation, is not clear. It may indicate a very strong effect from nearby sources with little effect from higher distant sources. As will be seen in the mathematical model, this relation would agree with the plot of Fig. 9, which would require a very strong local effect, either by a large "n" or a small "blind spot."

A Mathematical Model Relating Emission to Sulfation

A simple mathematical model was devised to relate the emission pattern to the resulting sulfation pattern. In this model, sulfation occurring at a given point due to emission from another point may be considered as proportional to the strength of the emission and inversely proportional to the distance between the two to some power, expressed as follows:

$$\text{sulfation} = \frac{k(\text{emission strength})}{x^n} \quad (7)$$

where k is a constant, x is the distance between the source and receptor, and n is an exponent.

As the distance between source and receptor becomes smaller, sulfation increases. This is true until a point is reached where the emission from a given elevated source will blow over the receiving point, striking the ground at a

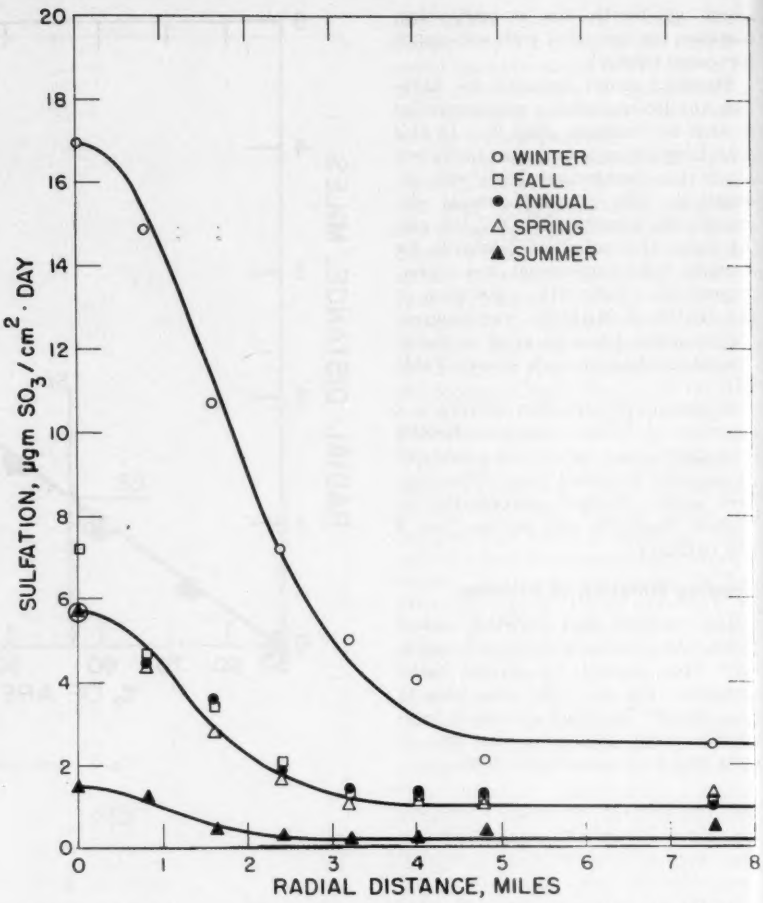

Fig. 5. Geometric mean sulfation by season vs radial distance from center of Nashville.

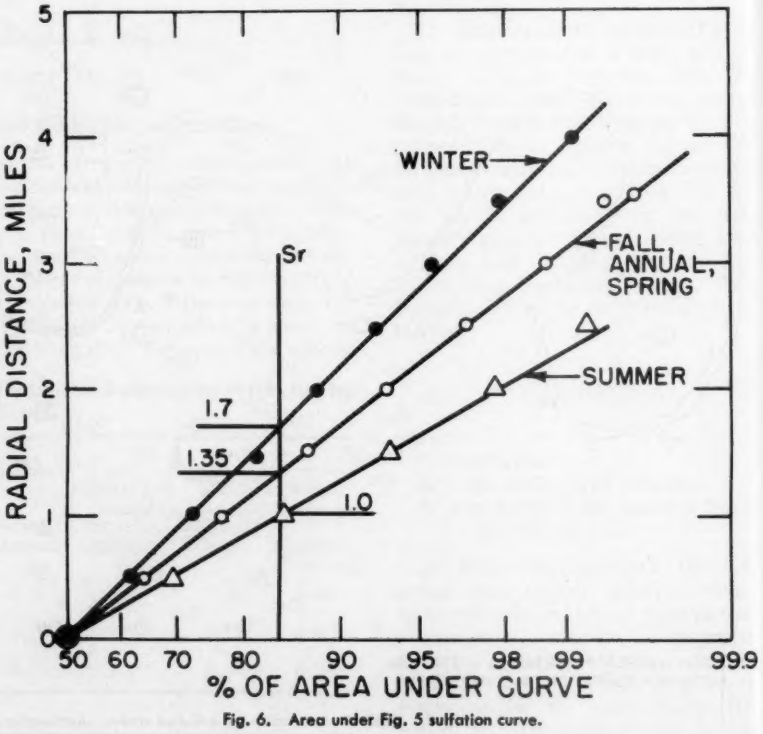

Fig. 6. Area under Fig. 5 sulfation curve.

greater distance. Thus, to the model must be added the concept of a "blind spot" at distances close to the source. To determine total sulfation, the effects of all of the emissions on a receiving point must be determined. Small differential source areas of Nashville were used, the emission from each area calculated from equation 2, and the effect on several receiving points was determined using an IBM 650 computer. One hour of electronic computing time per problem was required to accomplish the needed numerical integration.

If a pollutant source is considered analogous to a light source, with pollutant diffusing both horizontally and vertically, the effect on concentration (over long time periods, such as a season) would be expected to vary inversely as the square of distance between the source and receptor. Sulfation data from the Leicester, England, study[5] fit the inverse square law for points several miles from British cities. Similarly, for this study, the inverse square law appears to fit the data well (Fig. 9), indicating that the distribution of sulfation calculated from the emission model (in which s_r was 1.2 miles) shows standard radial deviations close to those measured for winter and annual-fall-spring results. If a "blind spot" 0.3 miles in radius from the receptor point is chosen, the value approaches the winter standard radial deviation of 1.7 miles. For a blind spot with a radius of 0.1 miles, the standard radial deviation approaches the 1.35 miles of the annual distribution. The higher the elevation of the emitting source, the greater should be the radius of the blind spot. Thus, if the "effective height" of emission were appreciably higher in the winter than for the rest of the year, this would agree with the model.

The mathematical model, which in effect treats all sources as if they emitted at the same elevation, will not explain the existence of high background levels in the nonurban areas. If the effect of high strong sources is considered, however, this effect could be explained. For instance, in the Tennessee Valley Authority study reported by Thomas and Davidson,[7] sulfation values were greatest 5.5 miles from a high, strong sulfur dioxide source. Such important sources could contribute markedly to an overall background of pollution into the countryside around Nashville. Also the control stations are not completely nonurban. Some homes are fairly close and could contribute to a heightened background. Thomas and Davidson[7] indicate that a true background sulfation level at a remote point is about 0.3 μgm $SO_3/cm^2/day$, or about the same level as measured at the Nashville control stations during summer.

In summary, the mathematical model relating source strength to sulfation indicates a fairly good fit to the study results when sulfation is considered as being inversely proportional to the square of distance between source and receptor. Also, the model yields a radial distribution approximating the bell-shaped sulfation distribution, with standard radial deviations close to those actually measured.

Summary

The U. S. Public Health Service Division of Air Pollution and the School of Medicine of Vanderbilt University conducted an air pollution study in Nashville in 1958–1959. As one phase of the study, sulfur dioxide emission and sulfation data were studied to determine their interrelation and variation as a function of radial distance from the center of town. Both sets of data appeared to fit a Gaussian or "normal" curve.

The variation in emission may be expressed as follows:

$$E = E_c e^{-1/2\left(\frac{r}{s_r}\right)^2}$$

where E is emission strength (in lb of $SO_2/mi^2/day$), E_c is emission strength at the center of Nashville, e is the transcendental number 2.718, r is the radial distance from the center of Nashville (in miles), and s_r is a new parameter, termed standard radial deviation, which is analogous to standard deviation in the "normal" equation. In Nashville, s_r was 1.2 miles, or about one-fourth of the radius of Nashville, for each season and the year as a whole.

A similar equation may be used to express sulfation in Nashville:

$$S = S_b + S_c e^{-1/2\left(\frac{r}{s_r}\right)^2}$$

where S is sulfation, S_b is the background sulfation 7.5 miles from the center of town, and S_c is the sulfation level in the center of town ($-S_b$). For sulfation, s_r varied from 0.2 of the radius of Nashville in the summer to 0.4 of the radius of Nashville in the winter. The fall, spring, and annual values were 0.3 of the radius of Nashville. Thus sulfation may be pictured as a bell-shaped dome over Nashville, superimposed on a background value for the surrounding area.

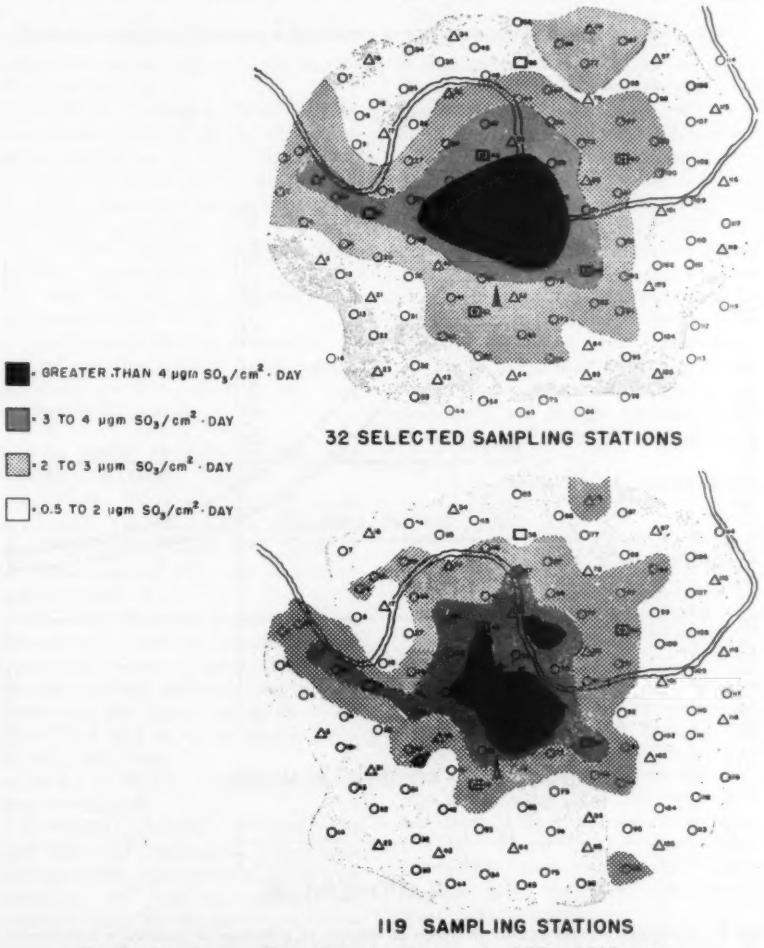
GREATER THAN 4 μgm SO3/cm2 · DAY
3 TO 4 μgm SO3/cm2 · DAY
2 TO 3 μgm SO3/cm2 · DAY
0.5 TO 2 μgm SO3/cm2 · DAY
32 SELECTED SAMPLING STATIONS
119 SAMPLING STATIONS

Fig. 7. Annual mean sulfation determined by networks of 32 and 119 stations.

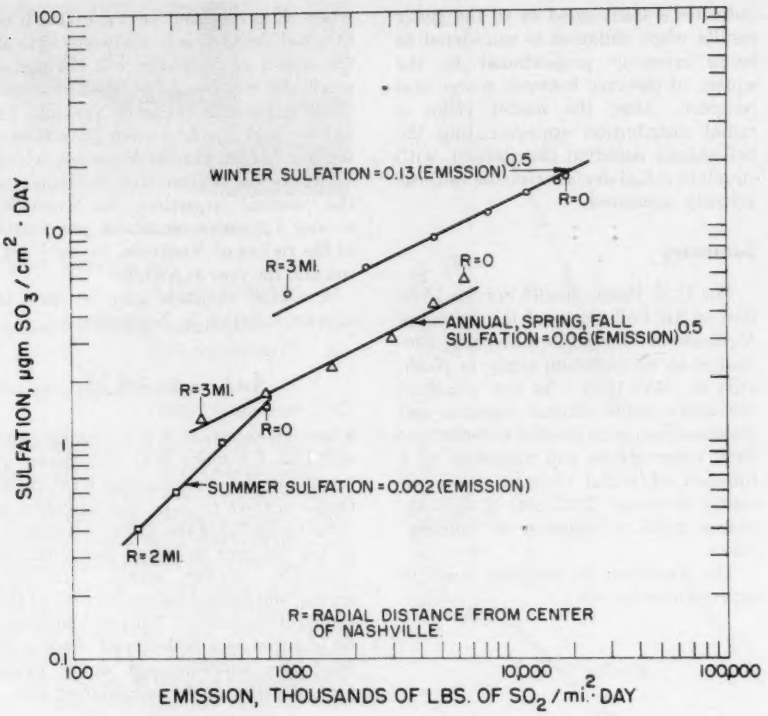

Fig. 8. Sulfation vs SO_2 emission by season at various radial distances from center of Nashville.

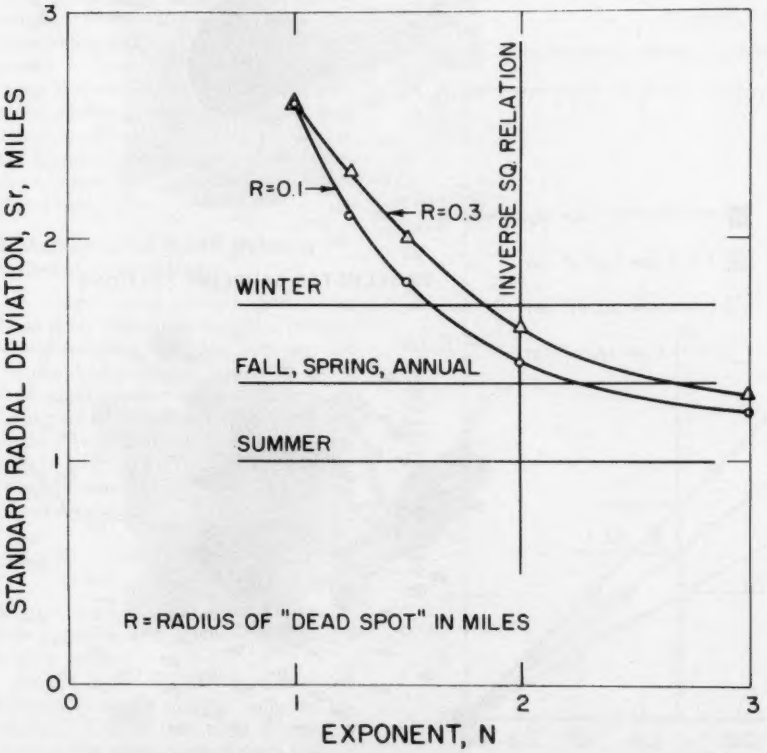

Fig. 9. Calculated standard radial deviation of sulfation as a function of variation in mathematical model.

The fall, spring, and annual sulfation values were of comparable magnitude. Winter sulfation at the center of Nashville was three times as great as the annual value; summer sulfation was one-fourth of the annual value. For each of the seasons, and the year, sulfation at the center of Nashville was approximately seven times the nonurban values.

A computer-solved mathematical model relating source strength to sulfation indicates a fairly good fit to the study results when sulfation is considered as being inversely proportional to the square of distance between source and receptor.

REFERENCES

1. L. D. Zeidberg, J. J. Schueneman, P. A. Humphrey, and R. A. Prindle, "Air Pollution and Health: General Description of a Study in Nashville, Tennessee," *J. Air Poll. Control Assoc.*, 11: 5 (May 1961).
2. D. M. Keagy, W. W. Stalker, C. E. Zimmer, and R. C. Dickerson, "Sampling Station and Time Requirements for Urban Air Pollution Surveys, Part I: Lead Peroxide Candles and Dustfall Collectors." Presented at the 53rd Annual Meeting of the Air Pollution Control Association, May 23–26, 1960, Cincinnati, Ohio.
3. A. F. Welch and J. P. Terry, "Developments in the Measurement of Atmospheric Sulfur Dioxide," *American Industrial Hygiene Association Journal*, 21: 4 (August 1960).
4. A. Parker and S. H. Richards, "Instruments Used for Measurement of Atmospheric Pollution in Great Britain," (In) Air Pollution, Proc. U. S. Tech. Conf. on Air Pollution, 1950. L. C. McCabe, ed., 538–41, McGraw-Hill Book Co., Inc., New York (1952).
5. Department of Scientific and Industrial Research, "Atmospheric Pollution in Leicester," Atmospheric Pollution Research, Technical Paper No. 1, H. M. Stationery Office, London (1945).
6. Meteorological Office: Department of Scientific and Industrial Research, "The Investigation of Atmospheric Pollution;" annual reports on observation, Nos. 18 and 20. H. M. Stationery Office, London.
7. F. W. Thomas and C. M. Davidson, "Monitoring Sulfur Dioxide with Lead Peroxide Cylinders," *J. Air Poll. Control Assoc.*, 11: 24–27 (January 1961).

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ABSTRACTS of LEGAL DECISIONS Relating to Air Pollution

LEGAL COMMITTEE, E. E. SCHULZE, Chairman, Air Pollution Control Association

***Koseris* v. *J. R. Simplot* Co., 352 P.2d 235 (Idaho 1960)**

ACTION: By owners of adjacent property, to abate nuisance and enjoin operation of fertilizer plant.

FACTS: Plaintiff owned a small storage building on two acres near defendant's fertilizer plant. Defendant's plant manufactures and converts phosphate ores into chemical fertilizer. This process results in the emission from the plant and entering into the air of a quantity of finely powdered dust and smoke, having an offensive odor, and sometimes carried by the wind to plaintiff's property. The defendant had spent large sums in improving the plant and in cutting down the dust emission.

TRIAL COURT: Granted injunction against the smoke, dust, odors, etc., and also an injunction against operation of the plant if it cannot conform (i.e., operate without dust, smoke, etc.).

SUPREME COURT: Reversed trial court and ordered it to admit defendant's evidence and render judgment accordingly. Defendant had offered evidence during the trial of its social and economic value to the community, and also evidence to the effect that only 0.1% dust emitted. The trial court refused to receive this evidence. The Supreme Court noted that the defendant operated a lawful business and was not a nuisance per se. The court then discussed the theory of comparative injury and concluded that the defendant should be allowed to operate its plant as long as it continues to use all the modern methods of dust control and continues to make an effort to improve its operations.

Defendant's only contention is that plaintiffs are not entitled to injunctive relief and if they are entitled to any relief it should be for damages under the theory of comparative injury.

***Lund* v. *Phillips Petroleum Co.*, 10 Utah 2d 276, 351 P.2d 952 (1960)**

ACTION: For damage to paint on plaintiff's autos.

FACTS: Defendant's Oil Refinery had a flare stack 45 ft high, in which waste gases were exhausted and burned. There was testimony that flames, smoke, and soot were blowing from this stack toward the parking lot where plaintiff's cars were located. Soot was deposited on the automobiles and when washed off the finish was pitted.

TRIAL COURT: Judgment for plaintiff.

SUPREME COURT: Judgment for plaintiff affirmed. The court also held that it was proper for the trial court to submit the case to the jury on the theory of *res ipsa loquitur*.

Defendant challenges submitting the case to the jury under the theory of *res ipsa loquitur* on the following points:

(*1*) There was no proof that the soot in question had come from defendant's flare stack.

(*2*) There was no evidence that defendant was negligent.

(*3*) On the contrary, defendant had exercised due care.

No other defenses were mentioned.

Most of the opinion concerned a discussion of the theory or *res ipsa loquitur* and jury trials.

***Sohns* v. *Jensen*, 11 Wisc. 2d 449, 105 N.W. 2d 818 (1960)**

ACTION: To enjoin the operation of an auto wrecking yard in violation of the zoning ordinance and to abate the nuisance created by the burning of junked automobiles.

FACTS: Defendant operated an auto salvage business wherein junked automobiles were cut apart with acetylene torches and subsequently burned There was no dispute as to the facts since they had been stipulated at a pretrial conference.

TRIAL COURT: Rendered judgment for plaintiffs.

SUPREME COURT: Affirmed and held that since defendant was not in business before enactment of the zoning ordinance he was not entitled to continue this operation as a nonconforming use. The court went on to say that where defendant's burning operation created extremely black, dense smoke containing soot as well as offensive and obnoxious smells, predominantly of burning rubber, oil and grease, the operation was enjoinable as a nuisance. The opinion indicated that at certain times the smoke penetrated into plaintiff's homes. The injunction was to issue only against burning of cars.

Defendant had contended that plaintiffs had an adequate administrative remedy which they did not exhaust. After an extended discussion of the zoning law involved, the court held that plaintiffs did not have adequate administrative remedies here and were entitled to sue under the "enforcement provisions" of the zoning ordinance. Defendant had also contended that plaintiffs were estopped to bring suit here because defendant had built up a good business. The court noted that defendant had not raised this point in the trial court, and therefore could not raise it in the Supreme Court. The court also noted that defendant's salvaging operations were not a conforming use under the ordinance and that there was enough evidence in the record to sustain the finding of the lower court.

The court also cited the attached case with approval.

***State ex rel Bd. of Health* v. *Sommers Rendering Co.*, 169 A.2d 165 (N. J. Sup. Ct. 1961)**

ACTION: To enjoin rendering company from causing foul odors in vicinity.

FACTS: The rendering involved consisted of cooking and pressing waste butcher shop fats and dead animal stock to produce a tallow with cracklings used for animal feed. When the plant was constructed, the area was rural, but now it is populated with many homes. There was evidence that unbearably foul and noxious odors emanate from the plant continuously when it is in operation.

TRIAL COURT: Issued an in-

(*Continued on p. 537*)

AIR POLLUTION AS RELATED TO CIVILIAN DEFENSE

FREDERICK KRAISSL, JR., P. E.*

As a veteran of both World War I and World War II and with continuing interested study in the succeeding years, it is possible to present some of the background and scope in the relationship of Air Pollution to Civil Defense.

Like most former reserve officers of the Chemical Warfare Service, trained from lessons learned during World War I, we were well grounded in the tactics and technique of Air Pollution to the discomfit and control of potential enemies or mobs as a mild application and with lethal effects when the situation required.

Counter-measures to chemical agents that might be used against this country were an integral part of this training from identification, individual and collective protection right through methods for decontamination. When World War II reared its ugly head, there was genuine concern about the possible use of chemical agents against civilian populations and essential facilities required for national defense.

It happened that I had been authorized to act as Director of Chemical Warfare Training in the Third Military area as then organized, on a voluntary basis and was engaged in the training of Unit Gas officers for the 78th Division. A directive came out of Second Corps Area Headquarters recommending that reserve officers not yet called to active duty participate in the Civilian Defense Program. This goes back to 1940 and it happened that I was also serving as an elected councilman of my borough of residence. The Mayor, knowing of my interest in this work, asked me to head up this activity.

New Jersey probably was the first state to formally authorize Civilian Defense Councils. We were able to report ours in being, and probably the first one in the United States. There was no office of Civilian Defense at that time. This all came along later. In times of stress all agencies can be counted on for co-operation. One of our national magazines had obtained early instructions given by the Austrian Ministry of Defense to deal with precautions to be taken for possible survival under air attack and I was given permission to reproduce them on slides for instruction purposes.

The Society of Military Engineers of which I am a member, also published *Effects of Bombs* which was current at that time. I was also given permission to reproduce these data on slides. There were some other supplementary sources and sufficient material for instruction purposes was put together before better information was made available through the office of Civilian Defense after it was organized.

I have always assumed that since the use of chemical agents against civilian populations was a threat and apprehension and since both War Gases and Incendiaries comprise chemical agents, two-thirds of the then existing hazards to civilians were specialties of the Chemical Warfare Service, and as all military services are trained in the use and defense against high explosives, the complete mission of Civilian Protection Training was given to the Chemical Warfare Service. In any event, Civilian Protection schools were organized and conducted by the Chemical Warfare Service for the office of Civilian Defense. Key personnel authorized by the office of Civilian Defense to take this training were sent to these schools in various parts of the country in decentralized areas that seemed to best meet the current needs.

After being ordered to active duty, it was my privilege to be assigned as an instructor to the War Department Civilian Protection school conducted in New Orleans. After these schools had completed their training mission, they were disbanded. By that time my identification with Civilian Defense had been accepted and I was given the dual assignment of Director of Training of the Eighth Region and Industrial Protection Officer of this same area.

While the authority and responsibility for Civilian Defense even under war regulations were always left with the states, the functions of the regional offices of Civilian Defense were coordination and training. They operated under a Civilian Director but were assisted by military advisers, like myself, who made available the desired military specialties under the supervision of senior officers operating from national headquarters in Washington. Even this phase of experience was accorded to me when I became Chief of Plant Protection Section and finally National Gas Officer at the time the war time office of Civilian Defense was closed by executive order and direct military supervision of Civilian Defense activities ceased.

While Army officers given this specialized training predominated, there were other military officers that must be mentioned, due to their great contributions. These were the officers of the Uniformed Section of the U. S. Public Health Service. When conducting schools in my capacity of Director of Training, it was my custom to always attempt to get one or more of these officers assigned as instructors. We frequently, interchangeably gave each other's lectures and the Public Health point of view as related to problems of contamination varying from requirements of collective protectors to the possible contamination of public water supplies, was a privileged association.

Very little has been changed in the intervening years concerning the factors involved, only in the magnitude of the problems and the effects. We still have the three hazards to civilian populations: (*1*) blast effect; (*2*) incendiary effect; (*3*) pollution effect.

Unfortunately, the air pollution effect is no longer limited to so-called war gases and biological agents, although their potential use should in no way be ruled out as they are still very effective weapons. Nuclear weapons produce all three effects at one time and consequently should they be used, we would have an automatic problem in air pollution even beyond the areas affected

* Formerly, Chief, Plant Protection Section Office of Civilian Defense at termination of World War II. Presently, President, Chief Engineer, The Kraissl Company, Inc., Hackensack, New Jersey.

by blast and incendiaries. It might be opportune to state here that while the efficiency and effectiveness to accomplish military missions were never doubted of pre-atomic chemical agents, it is my opinion that they were not used during World War II because each side knew the other had a complete chemical arsenal and each was afraid to start gas warfare. Where there is very close parity, the same principle and reasoning might apply to nuclear weapons.

It, therefore, behooves us to be sure of parity, and attempt superiority, to insure the best possible consideration of the advisability of not starting a nuclear war by an adversary. If people want to travel to the moon, this is good prestige advertising, but as long as we want to inhabit the earth, let us give priority to defending our position on it.

After data on the atomic bomb were available, I made a rather comprehensive study of what could be done to minimize the hazards assuming certain distances from point zero. After the introduction of the hydrogen bomb with intercontinental means of delivering it, dimensions and distances did not seem important.

Convincing a potential adversary that we would not supinely accept domination by terror should require evidence of intent to survive. Some type of fallout shelter is a good initial gesture and good publicity if extensively provided.

At the risk of annoying the public spirited individuals who have also given so much of their time and effort to this work, I must state that in my opinion the present type of organization is inadequate to deal with civilian defense. In the first place, un-uniformed personnel do not command much confidence. Populations over the ages have come to regard the uniform as a badge of competence to perform the service represented. You see this in uniformed police departments, fire departments, and even ambulance services. It seems unrealistic to discard these psychological advantages in civilian defense.

By now it must be clear to every one who has had some military background, that in times of national emergency, the National Guard becomes part of the Army of the United States or the equivalent in the Air Force. The states under such circumstances have no military force and in the past have organized state guards. I helped to train some of these state guard units in civilian defense in the area of my assignment.

Why must we wait until the National Guard is mobilized before we organize suitable state guard units? State guard units in the past have been organized along the lines of infantry. In my opinion they should be organized along the lines of combat engineers, with certain differences. Of every company, the first platoon should be trained and equipped as a military police platoon, the second should be organized as engineer fire fighting platoon, there was a T.O. and E. for this during World War II, and the third should be a demolition and rescue platoon.

Company headquarters should be trained and staffed to set up and operate a control center. Companies should be organized into battalions and battalions into regiments so that situations of various magnitudes could be handled. Provision should be made for medical state guard regiments, and if the states can afford it, at least part should be air units.

For a starter, I would like to see a division organized in each state composed of three regiments of specialized state guard engineers and two regiments of medical troops, one medical regiment organized like the old time medical regiments of a collecting battalion, ambulance battalion and hospital battalion, the other medical unit organized like Air Force medical troops of equivalent composition.

The co-ordination of civilian defense activities and the provision for training services should again be handled by military personnel. On the staffs of the civilian defense directors, on both the national and regional level, should be officers who are specialists in the required fields, including the United States Public Health Service. This type of organization would perpetuate the best of what was developed during World War II and make use of the experience gained in providing the suggested organization. Uniformed units of this type of state guard could be assigned joint occupancy of armories with the National Guard and trained on different and noninterfering schedules, probably to the advantage of both with good morale results.

The younger men in the National Guard would see in the older men of the state guard a determination to meet problems that might occur in the home area with competence and courage. The older men could profit from the enthusiasm and optimism of youth. Until National Guard units were called out, specially trained officers from both groups could be used for training purposes.

Judging from the voluntary participation of individuals in volunteer fire departments, auxiliary police departments, and ambulance companies, it is my opinion that there are still sufficient patriotic Americans to volunteer for a realistically organized state guard.

They could be uniformed from uniforms predating the new Army uniforms and the expense to the taxpayers of each state could be minimized.

They could be trained in defense against chemical and biological agents in their broadest sense which is another name for air pollution whether due to "fallout" or some other form of lethal contamination. They would be mobile and could go to the area where their services would be most needed until quasi-normal local government could be re-established. Since the basic problem is, in great part, in the field of air pollution, it might well be that leadership in sponsoring such a program could originate with those who have made this work a specialty, and perhaps some could participate in the training program.

It is my opinion that the determination to survive should be evidenced by positive action and if time and effort taken to prove this, convinces potential aggressors, or would-be conquerors, that any attempt to take military action against this country would be met by unanimous and competent counter measures, it would be well worth while, even if the measures provided are never required.

This philosophy coupled with the constant realization and appreciation that we imprint our coins with our national slogan "In God We Trust" to proclaim our motivating fundamentals, should permit a serenity and sanity in our national policy that would have a stabilizing effect on the peace of the world.

LEGAL ABSTRACTS

(*Continued from p. 535*)

junction.

On appeal, defendant contended that the Board of Health was not entitled to a judgment and that the lower court had exceeded its jurisdiction. It should be noted that defendant offered no evidence to contradict the Board of Health. Defendant then argued that before a nuisance can be enjoined by the Board of Health it must be such as would subject the defendant to indictment, and lastly, defendant argued that the language of the injunction was insufficient.

SUPREME COURT: The court held that the lower court had jurisdiction to abate such a nuisance on the application of the Board of Health. The court noted at page 167:

> "The corruption of air by noisome odors and smells, to the annoyance and inconvenience of the public, and hazardous to public health, constitutes a public nuisance suppressible by injunction at suit of the local Board of Health."

The court modified uncertain parts of the injunction and affirmed lower court.

As to defendant's argument on the point of indictment, the court noted

(*Continued on p. 539*)

TOP ATTENDANCE AT EAST CENTRAL ANNUAL MEETING

Under the capable co-chairmanship of Ralph W. Bourne, Chief Engineer of the Jefferson County Air Pollution Control District, and John M. Kane, Manager, Clean-Air Group, American Air Filter Corporation, APCA's East Central section attracted a record attendance at its 18th annual meeting held September 21 and 22 at the Sheraton Hotel, Louisville, Kentucky. Approximately 200 registrants from 22 states attended the meeting.

In addition to a top-flight technical program, previously announced in the August JOURNAL, addresses of welcome were made by Mayor Bruce Hoblitzell of the city of Louisville and Colonel W. D. Milne, chairman of Jefferson County's Air Pollution Control Board, at the Thursday luncheon program. Other highlights of the social part of the program included an address at the banquet by Dr. K. P. Vinsel, Executive Secretary of the Louisville Chamber of Commerce, and an amusing luncheon talk on Friday by Joe Creason of the *Louisville Courier-Journal*. A bus trip of the Louisville industrial area was the feature of Friday morning's program, and the round-table discussion group on the problems of odor control, dust and fume control, municipal incinerators, and Louisville Air Pollution control operations was extremely informative to participants.

New Officers

Albert Locuoco, Cleveland's Commissioner of Air Pollution Control, was elected chairman of the section to succeed Morton Sterling of Detroit. The new vice-chairman is Wright Erion of Columbus and the new secretary-treasurer is Paul Findlay, Toledo.

The 1962 meeting was scheduled for Columbus, Ohio.

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ROGER W. HOOKER APPOINTED BY APCA BOARD TO FILL VACANCY CREATED BY AUSTIN N. HELLER

Roger Wolcott Hooker, Senior Vice President of Hooker Chemical Corporation, 665 Fifth Avenue, New York City, has been appointed by APCA's Board of Directors to fill the vacancy created by the resignation of Austin N. Heller. In accordance with Article VII Section 4 Mr. Hooker will serve until the next Annual Meeting has been completed. He has been a member of APCA's Membership Committee since 1956, being primarily responsible for sparking a solicitation program for corporate support from the chemical industry. Prior to the move of Hooker Chemical Corporation's headquarters to New York City in 1959, Mr. Hooker served in many capacities for his company in Niagara Falls, New York. In addition to being a member of many professional societies he has served as president of the Chlorine Institute of America, board member of the National Industrial Conference Board, Inc., director-at-large of the Armed Forces Chemical Association, and member of the Synthetic Organic Chemical Manufacturers' Association. For many years he was recognized by the city of Niagara Falls, New York, for his many civic, cultural, and philanthropic contributions in the community. He is presently serving as a member of the Surgeon General's Advisory Committee on Air Pollution.

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VISITING ENGINEERS SWAP "TALES"

EXCHANGING KNOW-HOW—Five German engineers, including one from Dusseldorf, visited The Franklin Institute in Philadelphia, Pennsylvania, on September 14. The visitors came to the United States to study air pollution problems under the auspices of the German Productivity Center. Shown inspecting a catalytic muffler experiment in the Institute's chemical engineering laboratory are, from left: Josef Kramer, Technical Secretary of Verein Deutscher Ingenieure Commission for Clean Air and Verein Deutscher Ingenieure Committee of Dust Technology, Dusseldorf; Dr. Karl Schwarz, Chief Engineer of Technischer Uberwachungsverein Essen, Essen; Rudi Lenk, expert for inspecting motor vehicles and for investigating automotive exhausts, Essen; Wilhelm Bachmaier, Chief Engineer of Technischer Uberwachungsverein Bayern, Munich; Heinrich Oels, Air Pollution and Noise Control Department, Ministry of Labor, Bonn; and senior staff engineer Robert A. Baker, in charge of the Institute's air and water pollution research programs.

INCREASED RADIOACTIVE FALLOUT BECOMES EVIDENT; NO IMMEDIATE HEALTH DANGER EXISTING TO DATE

Evidence that radioactive fallout from the Russian resumption of nuclear weapons testing is falling on the United States has been announced by Secretary Abraham Ribicoff of Health, Education, and Welfare.

The Public Health Service Arctic Health Research Center at Anchorage, Alaska, reported that preliminary analysis of air samples taken September 5 showed a radiation level of seven micromicrocuries per cubic meter of air, 35 times the average daily levels of 0.2 micromicrocurie during August, said Secretary Ribicoff.

Dr. Luther L. Terry, Surgeon General of the Public Health Service, said that no immediate health danger exists in the increased fallout. He also said that, while he has no question of the fact that the sample shows fallout from Russian weapons testing, as a matter of scientific practice the analysis will be rechecked.

"During the past three years, in the absence of atomic bomb testing in the atmosphere, the level of radioactive fallout has gradually fallen," said Secretary Ribicoff. "But if these atmospheric tests are continued by the Soviet Union, the world faces again the threat of contamination of food, water, and air."

Dr. Terry pointed out that the seven micromicrocurie level reflected in the reading from the Alaskan test station is well below human tolerance levels and considerably lower than levels reported from Alaska on numerous occasions prior to the test moratorium in the fall of 1958.

The Surgeon General also said that the Public Health Service has tightened all of its radiation surveillance, but a complete picture of the effect of the Russian testing will not be done for several months.

The 45 radiation stations that sample air and rain or snow (first indicators of fallout) have been put on around-the-clock monitoring duty and asked to report within three hours any sample that shows a 10-fold increase above average radiation levels. In ordinary practice, air and rain is monitored on an eight-hour, five-day-a-week basis.

The 60 milk sampling stations have also been alerted to report any change in the iodine-131 content of milk. The first indication that Americans may be absorbing more radiation because of the Russian weapons testing program is expected to show up in higher amounts of radioactive iodine.

The 90 water sampling stations have been ordered to make radiation analyses of water samples on a weekly rather than, as previously, monthly basis.

Secretary Ribicoff said that tests show that the Russian resumption of atmospheric tests comes at a time when the test network has found radiation levels continuing to decline in water, air, milk, and other foods.

Mr. Ribicoff mentioned the following data on low, peak, and current radiation levels:

Milk

Milk has been measured for radioactivity longer than any other product and therefore shows most clearly the effects of fallout. Data from the first 12 raw milk sampling stations established in 1957 (there are now 60) averaged nine micromicrocuries of strontium-90 per liter of milk in 1958, went up to 13 in 1959, and was back to nine in the first quarter of 1961. Iodine-131 in milk averaged a high of 300 micromicrocuries per liter in late 1957, went down to 40 by the end of 1958, and in the first quarter of 1961 was below accurate measurement levels, i.e., less than 10 micromicrocuries per liter.

Wheat

The strontium-90 count from the 1958 crop from nine wheat producing states averaged 62 micromicrocuries per kilogram. Analyses of the 1960 wheat crop showed the average level had gone down to 25 micromicrocuries per kilogram.

Air

Levels of gross beta radioactivity in air decreased from an average of 12 micromicrocuries per cubic meter of air in November 1958 to a level of less than 0.1 micromicrocurie per cubic meter in May 1961. These data show the national average based on collections from 47 air sampling stations located in all parts of the country.

Water

For the last three years radioactivity levels in streams have been falling steadily. The maximum level of gross beta activity found in 1957–58 was 1334 micromicrocuries per liter while the highest found during the past year in streams not affected by uranium mining or production was 451. The latest reports include data collected from about 90 stream sampling stations throughout the United States.

Nominations for the Frank A. Chambers Award, Richard Beatty Mellon Award, and Honorary Members are due by January 1, 1962, to Dr. Louis C. McCabe, Chairman of the Awards Committee.

TRAINING COURSES TO BE PRESENTED

The Public Health Service, through its Division of Air Pollution, will present a one-week training course, "Medical and Biological Aspects of Air Pollution," December 11–15, 1961, at Cincinnati, Ohio, for physicians and other scientific personnel engaged in or responsible for studies of health-related effects of air pollution. The course reviews air pollution fundamentals (sources, engineering, chemical methods of assessment, meteorology, and control procedures) and considers the health effects and biological damage resulting from air pollution, the experimental evidence on animals (including animal research and laboratory methodology) and experimental studies with humans, maximum permissible concentrations for substances vented into the outdoor air, and associated legal and administrative problems.

The Division of Occupational Health, Public Health Service, will conduct simultaneous courses January 8–19, 1962, at the Occupational Health Research and Training Facility, Cincinnati, Ohio. "Industrial Hygiene Engineering" is designed for industrial hygienists and engineers in the field of occupational health who have a degree in engineering or in the physical sciences. "Industrial Hygiene Chemistry" is designed for chemists in this field who have a degree in chemistry or chemical engineering, or in the physical sciences with a minor in chemistry. During the first week, trainees for both courses meet together for instruction in industrial hygiene and medicine, toxicology, and principles pertaining to evaluation of the environment. For the hygienists, the second week's work covers temperature and humidity measurements, illumination, noise measurement and control, and industrial ventilation; for the chemists, laboratory analyses for lead-free silica, and solvents, and spectroscopy, polarography, x-ray diffraction, electron microscopy, and gas chromatography.

Address applications for the courses or requests for information to the Chief, Training Program, Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio.

LEGAL ABSTRACTS

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that this requirement merely meant that it must be a public nuisance rather than a private nuisance and that this situation was clearly a public nuisance.

The court noted at page 168 that there was nothing unusual about granting injunctions against fat rendering plants.

NEWS FROM THE CONTROL DISTRICTS

Bay Area

James P. Kenny, appointed by the Contra Costa County Board of Supervisors to fill the vacancy caused by the resignation of W. G. Buchanan, attended his first Board of Directors along with Joseph Hunter of Burlingame, the new member of the District's three-man Hearing Board.

Clifford W. Swenson, general contractor of San Jose, was named to fill the vacancy on the District's 20-man Advisory Council, resulting from the resignation of William Nicholson, also of Santa Clara County.

Executive Secretary, Patrick J. Moran, an employee of the District since February 1956, will leave to go into private business, as previously announced, on September 11. The position will be eliminated when the new Chief Administrative Officer is named.

Control Officer Benjamin Linsky presented a "progress report" in which he outlined the priorities being given to various industrial, institutional and commercial operations which must comply with District regulations. Mr. Linsky also reported to the Board on enforcement, technical and public information work now in progress. He was asked for a report at the next regular meeting on current work on atomic fallout measurement being done in the six counties by various public agencies.

It was suggested by Director William Blake, San Francisco Supervisor, that the District's library should become the information center for all such radiation information being collected.

New York City

Proper servicing of automotive vehicles now, after increased driving during the summer, is needed to help reduce air pollution and to save money for owners and operators of the vehicles, according to Arthur J. Benline, Commissioner of the New York City Department of Air Pollution Control.

"There are more than 1,500,000 vehicles of all kinds registered in New York City and many more thousands enter the City each day, especially from New Jersey," Commissioner Benline said. "The smoke and gases from these vehicles constitute one of the major air pollution problems here."

Commissioner Benline pointed out that at the present time there are no exhaust control devices for automotive vehicles, although the "crankcase blow-by" device, now available, controls approximately 30% of the total pollution from a vehicle which blows past the piston rings. "Until control devices for the exhaust are perfected, the proper maintenance and operation of vehicles can do much to reduce air pollution," Commissioner Benline said. "In addition, such care has the added benefit of saving the motorist money on gasoline, oil and repairs."

Free copies of the Department's pamphlet, "Does Your Exhaust Pipe Smoke?" which contains information on the proper care and maintenance of automotive vehicles, can be obtained upon request to Publications, Department of Air Pollution Control, 15 Park Row, New York 38.

ASME SPONSORS NEW COMMITTEE

A new committee, whose aim is to bring engineering skills to bear on problems of air pollution and refuse disposal through burning, has been formed under the auspices of The American Society of Mechanical Engineers. It held its first meeting in New York last June. Approximately 50 engineers attended the organization meeting.

According to William Raisch, general chairman of the Incinerator Committee, plans have already been made to sponsor a series of meetings in the New York metropolitan area during 1962. Members will discuss such problems as the design of modern incinerators, that will operate efficiently without adding to air pollution.

With greater emphasis being placed on the problems of air pollution control, and the fact that many towns and cities may soon be compelled to construct incinerator plants, the Committee feels that the Society should lend its assistance in the orderly planning of such installations. In the past, incinerator plants were sometimes built without due regard to air pollution control.

Mr. Raisch commented that the new committee plans to co-operate with similar organizations or subdivisions of existing engineering societies.

In addition to the main committee, seven subcommittees have been established dealing with, respectively, design, stokers, materials handling equipment, refractories, auxiliary equipment, operation, and air pollution control. Invitations to participate in the work of the subcommittees have been issued by the committee to any interested individuals.

Mr. Raisch, a consulting engineer of Garden City, New York, has long been active in the field of design and operation of incinerator plants.

NEW AIR POLLUTION SAMPLING NETWORK CREATED RECENTLY

Creation of a special air pollution sampling network covering Washington, D. C., and the nearby areas of Maryland and Virginia was announced by Secretary of Health, Education, and Welfare Abraham Ribicoff.

The network began operation September 26 under the joint sponsorship of the U. S. Public Health Service and the Washington Metropolitan Regional Conference.

Mr. Ribicoff, who recently warned the automobile industry to install "blowby devices" on new 1964 cars or face the prospect of compulsory legislation, said that the sampling network will measure total oxidant, a type of air pollution associated with smog formation. Oxidant is produced in the atmosphere by the photochemical action of sunlight on emissions from auto exhaust and other sources.

In addition to the U. S. Department of Agriculture Research Station in Beltsville, Maryland, six local governments are participating in the network. They are: the District of Columbia, the Counties of Fairfax and Arlington and the City of Alexandria in Virginia, as well as the Counties of Montgomery, and Prince Georges in Maryland.

Studies Show Need for Control

"Studies conducted already," said Frank J. Lastner, Prince Georges' Commissioner and Chairman of the Health and Welfare Committee of the Washington Regional Conference, "make it clear that the entire Washington Metropolitan area should prepare now to meet the air pollution problem which will inevitably accompany continued growth in population and motor vehicle traffic. Moreover, there is evidence to suggest that the problem is already with us. Air pollution here has produced complaints of eye irritation on several occasions and the U. S. Department of Agriculture's station in Beltsville, Maryland, has reported ozone damage to tobacco plants."

Sampling Site Locations

Location of the sampling sites are as follows: Alexandria Health Department, Alexandria, Virginia; Arlington Hospital, Arlington, Virginia; District of Columbia Health Department in downtown Washington; Fairfax County Health Department, Fairfax, Virginia; Montgomery County Health Department, Rockville, Maryland; Prince Georges County Health Department, Cheverly, Maryland; and the U. S. Department of Agriculture Research Station, Beltsville, Maryland.

TRANS-ATLANTIC PHONE CALL HI-LITES BRIGHTON MEETING

The October 5 Trans-atlantic telephone call between APCA in Pittsburgh and the National Cleaner Air Conference in Brighton, England was a high-light of the Conference.

Speakers for APCA were Arnold Arch, Executive Secretary; Dr. W. L. Faith, President of APCA; Dr. R. A. Prindle, Deputy Chief, Division of Air Pollution, USPHS; and Dr. E. R. Weidlein, scientist.

Conference delagates who spoke were: Arnold Marsh, James Goodfellow, Dr. Patrick Lawther, Douglas Lister, and Sir Hugh Beaver.

The Hon. Joseph M. Barr, Mayor of Pittsburgh, extended official greetings to the Mayor of Brighton to open the program.

Under discussion were the national goals of air pollution in both England and United States; sources of air pollution; maximum allowable concentration standards; biological indicators of pollution; research, budgets, organization, and the international picture of air pollution.

In regard to the air pollution problem in the USA, Mr. Arch said, "Whatever the intensity of the problem, the local official knows co-operation through the community is the key to its solution."

Faith Comments on West Coast

In discussing the pollution problems of homes, industry and motor vehicles on the west coast, Dr. Faith commented that "our biggest problem is the development of controls which will protect the public but at the same time not put an undue burden on industry... In this connection, one of the Air Pollution Control Association's primary activities is the technical industrial committees where control officials and industrial representatives are engaged in co-operative studies of reasonable and economic abatement methods."

The discussion was held over high-fidelity telephone cable between Brighton and the Mellon Institute Auditorium in Pittsburgh. The program was sponsored by Pfizer Ltd. and was attended by over a thousand between England and USA.

AUSTIN HELLER RESIGNS

Austin N. Heller, who was elected to APCA's Board of Directors in 1960, to serve as the chemical industry member to the end of the annual meeting 1963, has recently changed his employment category. He is presently working as a special consultant to the USPHS at the R. A. Taft Sanitary Engineering Center in Cincinnati. Accordingly then, since he is no longer employed by the Chemical industry he has tendered his resignation, effective July 25, 1961, from APCA's Board of Directors.

CALIFORNIA BOARD SAYS CONTROL DEVICE OKAY

The State Motor Vehicle Pollution Control Board issued its first certificate of approval for a crankcase emission control device.

The Board announced that the Positive Crankcase Ventilation System, manufactured by the AC Spark Plug Division of General Motors, had met the criteria for such devices and had passed all tests.

Today's Board action will not make the mandatory provision of the California law effective since only one device has been approved and then only for 1961 or newer models. Two devices in each category are needed for certification.

However, most of the new cars shipped to California from Detroit already are factory-equipped with this device. The cost is under $6, depending on the size of the car.

This first certificate of approval was based on three volumes of test reports submitted by the Board's staff which indicated that the AC device met all State requirements. Other reports also showed that the device has proved its serviceability over the last 20 years on military vehicles and commercial trucks.

Others Being Studied

At the same time Dr. John Middleton of Riverside, MVPC Board chairman, said that five other applications for crankcase control devices are being studied by the Board's engineering staff.

"We expect several of these will be found acceptable in the very near future," he said.

The crankcase emission control device will reduce motor vehicle pollution by 25 to 30%, while an exhaust control system will eliminate another 60 to 65% of the emissions. Eight applications for the latter are now before the Board.

Dr. Middleton pointed out that crankcase devices already are in production and were voluntarily put on about 500,000 new cars during 1961.

The next meeting of the Board will be October 13 in Sacramento.

Personalia

Don H. Taylor has joined Wheelabrator Corporation, Dust and Fume Control Division, Mishawaka, Indiana, as a regional engineer and has been assigned to a territory in northern Ohio and Michigan, including the cities of Cleveland and Detroit. His headquarters have been established at Wheelabrator's regional office in Cleveland.

* * *

An important aspect of urban development and redevelopment, air pollution control, will be studied by **Dr. Seymour Calvert,** Associate Professor of Chemical Engineering at Case Institute of Technology, as the result of a grant from the United States Public Health Service.

This is the fourth successive year that funds have been made available for Dr. Calvert's "Basic Study of Air Pollution Wet-Scrubbers." The new $29,210 grant brings the total project value to $77,165.

* * *

Research-Cottrell, Inc., Bound Brook, New Jersey, announces the appointment of **William C. Osborne** as Vice-President in charge of engineering and research.

Mr. Osborne, who also becomes a member of the Board of Directors of the corporation, will be responsible for all engineering and research activities of Research-Cottrell, one of the country's leading industrial air and gas cleaning manufacturers.

* * *

The Division of Air Pollution, U. S. Public Health Service, has announced the appointment of **Eugene H. Krackow,** Member toxicologist, as Assistant Chief, Laboratory of Medical and Biological Sciences. Mr. Krackow will have the administrative direction of intramural biomedical research at the laboratories of the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio. This research is designed to determine the effects of air pollution on man and animals.

* * *

Dr. Robert J. M. Horton, formerly Professor of Epidemiology at the University of Michigan, was recently appointed Chief, Field Studies Branch, Division of Air Pollution in the U. S. Public Health Service.

* * *

Dr. David L. Coffin, pathologist, is the newly appointed Director of Research of the Division of Air Pollution's Laboratory of Medical and Biological Sciences, U. S. Public Health Service.

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NEW COMMITTEE FORMED ON EDUCATION, TRAINING

A committee on Education and Training has recently been formed and held its first meeting in Washington, D. C. The group is known as Committee S-11 and has outlined objectives which will further the educational phases of the APCA program.

The members include:

Dr. E. R. Hendrickson, *Chairman*
College of Engineering
University of Florida
Gainesville, Florida

Dr. A. M. Fisher
School of Hygiene
University of Toronto
Toronto 5, Canada

R. E. Hatchard
Oregon State Sanitary Authority
P. O. Box 231
Portland 7, Oregon

Dr. H. J. Paulus
School of Public Health
University of Minnesota
Minneapolis 14, Minnesota

Dr. A. T. Russano
Department of Environmental Health Engineering
California Institute of Technology
Pasadena, California

J. P. Sheehy
Taft Sanitary Engineering Center
4676 Columbia Parkway
Cincinnati 26, Ohio

B. J. Steigerwald
Department of Civil Engineering
Case Institute of Technology
Cleveland 6, Ohio

Dr. H. D. Townsend
Chambers Works
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Penns Grove, New Jersey

If anyone has any suggestions concerning the activities of this committee, please send them to the chairman.

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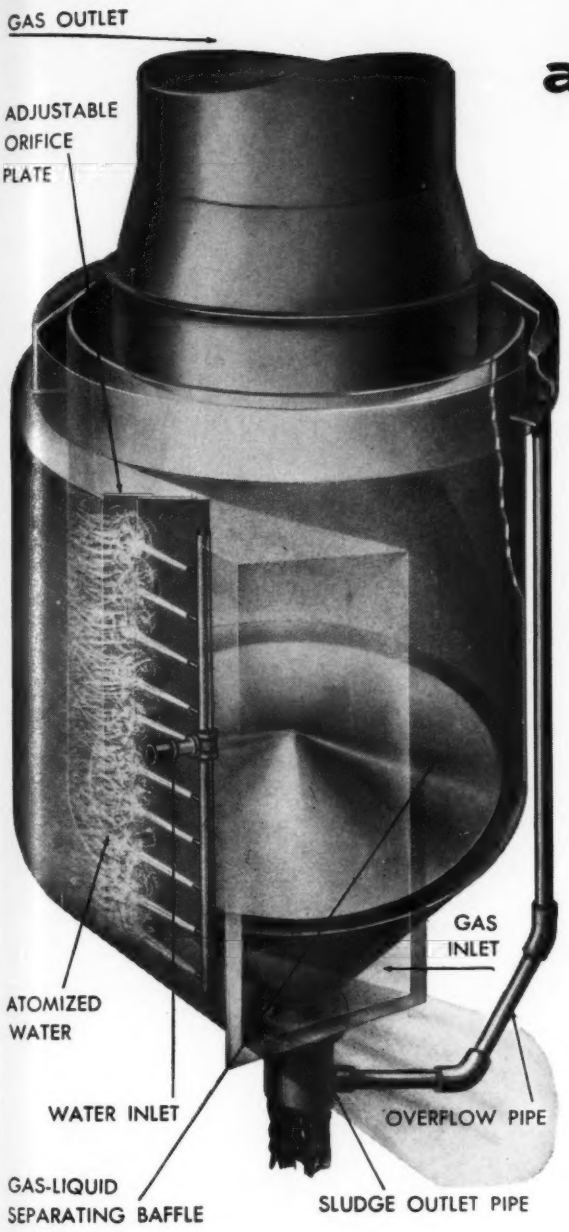

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